The Final Report

on the

Statistical Performance Evaluation of an Enhanced Automatic Ply Separation and Feeding System for Apparel Fabrics (Improvement of Clupicker, Phase II)

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and
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While the Clupicker system is one of the best loading systems commercially available, industrial experience has shown that the Clupicker system requires proper maintenance and accurate machanical adjustments for efficient operation. The skill level or training in many factories is often insufficient to maintain the system at its optimum working condition. Production trials at CAR have indicated that disrupted stacks and changes in fabric types can disrupt production efficiency. NCSU studies have shown that it is not easy for the operator to adjust important mechanical parameters. These studied also show that the Clupicker pickup is not the preferred top ply grasping device in certain instances. These problems combined tend to inhibit the acceptance of Clupicker technology. This report presents the findings from the implementation of the Phase I system modifications and recommend improvements or immediate commercialization.

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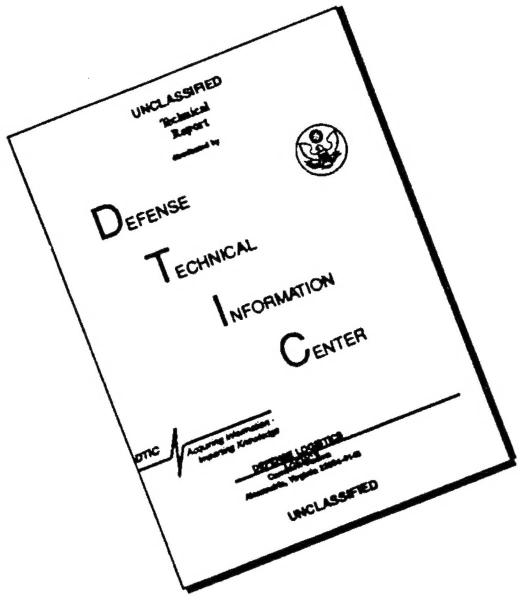

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Abstract

Chapter 2 clearly demonstrates that for shirting fabrics in general the Modified Clupickers consistently outperform the Original Clupickers. Experimental data obtained during this project show that the Original Clupickers have a performance range between 97.51% and 98.68%, and the Modified Clupickers have a performance range between 98.76% and 99.23%. (Previous estimates were 99.5+% and 99.9%.)

These Clupicker performance values were obtained by running three Original Clupickers on one half of a Jet Sew 5001 Automatic Front Loader and three Modified Clupickers on the other half of the Loader. Each side of the Loader processed 2790 plies made from 18 different shirt fabrics (experimental details are given in Chapter 2). In addition, each side of the Loader processed 2875 plies of white oxford shirt fabric. So, to obtain the mispick data each group of three Clupickers (Original and Modified) had to pick 5665 plies made of 19 different shirt fabrics.

Chapter 2 also shows that a simple device (a Bologna Slicer) can make the troubleshooting of Clupickers fast and accurate. In some production environments the Bologna Slicer can help mechanics increase the Original Clupicker performances to the point that Modified Clupickers may not even be required. Determining how Clupickers fit into production environments was the job of Chapter 3, however.

Chapter 3 shows that before a company can conduct a cost analysis on any piece of equipment, the company must understand how the equipment affects the manufacturing environment. In the case of the Clupickers this involves first confirming that the Clupicker processing speed is limited by the Jet Sew Hemmer. Next, the way a Jet Sew Hemmer fits into an apparel manufacturing environment is modeled. Then the Jet Sew Hemmer's critical production time-path is determined. Time-based information is then added to the critical time-path. The result is a production model for the equipment in question (a completed model is shown in Figure 3-3). Finally, the basic validity of the production model is checked.

For the Jet Sew Hemmer this is done in the last section of Chapter 3 using a calculator program developed in Appendix J. The check involves determining if the Clupickers create more errors than can be corrected in the time available (see Chapter 3 for a more detailed explanation). Once the production model is developed and checked, a detailed cost analysis for a variety of production scenarios is performed.

Chapter 4 is devoted entirely to performing comprehensive Clupicker cost analyses using Clemson Apparel Research's Apparel Manufacturers' Capital Investment Advisor (AMCIA) program. The resulting data is analyzed for trends, and two simple equations are produced which can predict the net present values associated with a variety of production and Clupicker related purchase scenarios. Chapter 4 emphasizes the fact that, despite favorable cost analyses, companies looking to justify Clupicker purchases based on labor savings alone may be disappointed. Also, companies will be disappointed to learn that Hemmer/Loaders require constant human monitoring. This does not mean development of the Modified Clupickers was a waste of time, however.

The Modified Clupickers will reduce the number of times an operator must correct mispick conditions by giving the Loader's the ability to automatically correct for large fabric variations. The Loader's can also automatically correct mispicks if Jet Sew modifies the Loader's controls so that when a mispick condition is sensed the Loader drops the offending plies and automatically attempts to repick the top-most ply. The only condition which the Loader's can not compensate for is poor bundle quality. Methods for achieving high bundle quality are listed at the end of Chapter 4 and again in Chapter 5 which summarizes the whole paper.

Any company that understands and follows the recommendations given in this paper can expect the Modified Clupickers to increase the Hemmer/Loader's production capacity. Increasing a Hemmer/Loader's production capacity is only useful if it avoids a production bottleneck, however. If increased production capacity does not eliminate a production bottleneck then the increased capacity is not necessary. In other words, improving a hemming operation by purchasing a Jet Sew Hemmer and Loader equipped with Modified Clupickers only makes sense if the hemming operation is a true production bottleneck.

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Chapter 1 - Introduction

Background

The Jet Sew Clupicker ply separation and loading system is one of the most flexible and reliable automated mechanical systems for loading apparel fabrics and similar materials. There are many of these loading systems in operation in industry. This system has been used or studied by a number of research organizations including NCSU, $(TC)^2$, Georgia Tech, and Clemson Apparel Research.

Problem

While the Clupicker system is one of the best loading systems commercially available, industrial experience has shown that the Clupicker system requires proper maintenance and accurate mechanical adjustments for efficient operation. The skill level or training in many factories is often insufficient to maintain the system at its optimum working condition. Production trials at CAR have indicated that disrupted stacks and changes in fabric types can disrupt production efficiency. NCSU studies have shown that it is not easy for the operator to adjust important mechanical parameters. These studies also show that the Clupicker pickup device is not the preferred top ply grasping device in certain instances. These problems combined tend to inhibit the acceptance of Clupicker technology.

Need

Despite deficiencies in existing Clupicker technology, many high volume production facilities (19,000+ units/week)[1.1] are willing to invest in Clupicker technology. These production facilities have sufficiently high production volumes that they can justify purchasing several loading devices and hiring a full-time mechanic to maintain the picker systems (loaders). Such high volume companies offset the cost of several loaders and a full-time mechanic with savings derived from the elimination of machine operators hired to manually load fabric plies into automated sewing machines. The justification of Clupicker systems is further enhanced if the associated sewing operations form production bottle-necks.

The real need for improved Clupicker technology comes from the small-to-medium production facilities (2,000+ to 15,000+ units/week)[1.2]. These facilities have the same production problems as the high volume facilities but can not offset the cost of Clupicker technology with labor savings. There are many reason for this (see the Improvement of Clupicker - Phase I final report, DLA900 87-0017, D0-0024)), but two of the main reasons center around the Clupicker's reliability and flexibility.[1.3]

In production environments large enough to justify a full-time Clupicker mechanic, Clupicker malfunctions can be quickly identified and repaired using the skills the mechanic develops from constant exposure to picker related problems. Also, in large production facilities the production runs are long enough to allow the mechanic time to identify the primary source of picker related handling problems. In smaller manufacturing facilities mechanics never get the opportunity to develop a Clupicker knowledge-base because the production runs are not long enough to justify machine exploration or validate machine adjustments.

Solution

The most elegant way to address the Clupicker problems of reliability and flexibility was to explore Dr. Tim Clapp's concept of a "Self-adjusting Clupicker". NCSU, JetSew, and CAR developed and tested the Self-adjusting Clupicker (a.k.a. The Modified Clupicker) as part of the two phase "Improvement of Clupicker" project.

Phase I of the project had two primary objectives. The first objective was to identify the primary factors inhibiting Clupicker acceptance among small and medium apparel producers. The second objective was to design and construct an enhanced ply separation system that eliminated or minimized the affects of the critical factors inhibiting acceptance of the automated Clupicker ply separation and loading system, while maintaining or reducing manufacturing costs.

Phase II of the project also had two primary objectives. The first objective was to design and implement impartial statistical experiments to test the success of the Phase I Clupicker system modifications. The second objective was to recommend improvements or immediate commercialization.

Note

Readers should note that at the time this report was written, all of the industry processes, equipment, and opinions listed in this report were current and are therefore discussed in the present tense. Developments made during the course of the Improvement of Clupicker Project are reported in the conventional manner, in the past tense.

Inter-Office Memorandum

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Chapter 2 - Clupicker Experiment

Original Experimental Design

In the Phase II proposal CAR submitted a statistically designed experiment. The experiment was designed according to the original experimental design-outline provided in the Fundamental Concepts in the Design of Experiments, Third Edition, by Charles R. Hicks.[2.1] A detailed description of the original experimental design is given in Appendix A.

The original designed experiment was based on a number of assumptions:

1. Performance estimates of 99.5% for the Original Clupicker and 99.9% for the Modified Clupicker, were reasonable.[2.2]

2. Once the fabric pieces to be tested were cut and arranged in neat bundles, the experiment could begin.

3. All the Clupickers were properly setup.

4. All the Clupickers were properly maintained.

5. Once configured for the experiment, picker performance would not vary substantially over the length of the experiment.

6. Manual fabric realignment would be sufficient for conducting repeat tests using the same fabric samples.

7. Once the experiment began, it would take a maximum of one week to complete.

8. 16,000 plies could be processed in four days, or two-thousand plies could be processed per day.

9. Side-to-side picker change-overs would take half a day each with minimum disruption to the loader performance.

As shall be shown, most of these assumptions proved false, but the preparations made for beginning the experiment proved useful.

Sample Preparation

The first step in preparing to conduct the Clupicker performance test was to cut short sleeves (a.k.a. the experimental units) from a variety of fabrics. Eighteen different types of shirt fabric were selected at random for running the Clupicker experiment (see Appendix B). The different fabrics were spread using an Eastman Advance 3000 Automatic Spreader, and were cut according to the Army, AG 415, dress-shirt, short-sleeve pattern. The fabric cutting was done on a Gerber GERBERcutter S-3200 medium-/high-ply cutter.

Once the fabric was cut, the bundles were pulled, and the perfect sleeves were separated from the damaged and partial sleeves. The sleeves were then sorted into bundles based on the individual fabric types. These bundles were then divided in half with odd sleeves being thrown away. The individual fabric bundles were than stacked one on top of the other to form two identical stacks of fabric showing distinct material zones.

This process was done to ensure that the sleeves between each stack were from random locations on the same roll of fabric. To ensure that the plies within the stacks were equally random, the two identical stacks of fabric (with the distinct material zones) were then randomly arranged so that each ply within each stack was different from the next ply within the same stack. To ensure parity between the two stacks, however, the random fabric distributions within each stack were kept the same. In this way CAR created two identical stacks of sleeves. Each stack of sleeves contained the same random distribution of fabric types. The sleeves were cut from the same random selection of fabrics, but sleeves made from the same fabric type came from randomly selected rolls if fabric and random locations within those rolls of fabric.

Initially, the two stacks, consisting of 570 plies each, were going to be reused for the duration of the test. This naïve decision was based on the assumptions that destacking the shirt sleeves would not damage the sleeves, and that the Loader's alignment system could accurately realign the plies. Both assumptions proved false, and will be discussed in more detail later. In any event, the two stacks (or bundles) with 570 plies each, proved extremely difficult to handle. Simply lifting the bundles disrupted the ply-to-ply alignment, and so the two large bundles were each broken into four smaller bundles. The smaller bundles were easier to manage and did not suffer extensive ply-to-ply misalignment when handled. The names and ply sequences of the four smaller bundles are described in Appendix C.

With the test bundles in hand, a block of one week was set aside to conduct the Clupicker tests. The week of July 4th was selected as the best week for running the experiment. During the July 4th week most apparel and textile facilities experience substantial slow-downs. CAR is no exception.

Setup Procedures

As stated in the section "Original Experimental Design", the original experiment was designed under the assumption that the Clupickers (both Original and Modified) had been properly setup and properly maintained. CAR routinely demonstrated the two Clupickers running side-by-side on Jet Sew's 5001 Automatic Front Loader. Even now, as part of CAR's ongoing demonstration site, all of the machines are run as they would be in a small (2000+ units/day) manufacturing facility. It was therefore reasonable to assume that the Clupickers would be well setup and maintained because conditions otherwise would stop the demonstration site from functioning properly.

Assuming the Clupickers were in good working order, the Clupickers on the Jet Sew Loader were adjusted so that the positions of each hold-down finger relative to its associated picker was maintained. To minimize disturbance to the picker setup, the three Modified Pickers, spread apart over the right elevator table, were left alone. The three Original Pickers, located close together over the left elevator table, were moved so that their spacing matched the spacing of the three Modified Pickers.

CAR also made a number of modifications to the Loader in order to facilitate bundle reprocessing and error tracking. To facilitate bundle reprocessing, the Loader was modified to run automatically but independently of the Jet Sew Model 2621 Centerplaite/Sleeve Hemmer. CAR felt the modification was necessary to avoid passing the short sleeves through the Hemmer's folding group which would eventually crease the sleeves. With the Loader separated from the Hemmer, the Loader was made to cycle automatically by moving the Conveyor Scanner.[2.3]

Initial Performance Results

With test samples in hand, a block of one week available, and Jet Sew's Loader setup, CAR began the designed experiment. The initial results were disastrous (Appendix D).

The first test bundles loaded were the Chambray bundles (see Appendix B). In pass number one (i.e., in the first complete processing of the Chambray bundles), out of 69 plies in each Chambray bundle, there were 23 mispicks in the Original Clupicker bank and four mispicks in the Modified Clupicker bank. Following this run the bundles unloaded from the back of the loader were found to be in complete disarray. Therefore, the two Chambray bundles had to be carefully restacked by hand. In pass number two there were 30 mispicks in the Original Clupicker bank and five mispicks in the Modified Clupicker bank.

From these initial results it was obvious that the Clupickers/Loader combination was not working properly, and that the original designed experiment could not proceed until machine adjustments had been made to improve the Clupicker/Loader performance. The initial results also showed that many of the underlying assumptions, on which the original designed experiment was based, were completely false.

Problems

From the initial test runs made using the Chambray bundles, it was obvious that many of the initial assumptions CAR had made, with respect to setting up the Clupickers and Loader, were wrong. Finding and correcting the associated problems proved to be a difficult and time-consuming task.

The first step in correcting the Clupicker performance problems involved isolating the source of those problems. The only way to isolate the problem sources was to create a simple test that could be repeated again and again with consistent results. CAR decided to create two large bundles of Army AG 415 short-sleeves cut from plain white oxford cloth. These bundles were identified as the "White" bundles. The white bundles were cut from a single roll of fabric and were completely randomized.

With the White bundles in hand, CAR conducted the a series of diagnostic tests (see Appendix E). In a first run, most of the problems were on the Original Clupicker side of the Loader (Clupicker 4, 5, and 6). In the second run, which arbitrarily consisted of picking 106 plies, Original Clupickers four and five and Modified Clupicker two were having problems. Following adjustments (which are described in the next section) the Chambray bundles were run again. Clearly, Original Clupicker number four was still malfunctioning.

Based on these three diagnostic tests CAR decided to use the White bundles to adjust the Clupicker/Loader and to use the Chambray bundle to check those adjustments. During this iterative adjustment process flaws in the underlying designed experiment/setup were exposed.

Assumption that Clupickers are Properly Setup is False

The test team's first major flaw was operating on the assumption that the Clupickers were properly setup before being repositioned for the Clupicker experiment. Although CAR was using the Loader in the daily operation of its demonstration site, the close positioning of Original Clupickers prevented poor picker performance from surfacing. The close proximity of the Original Clupickers meant that if one picker mispicked no fabric drape occurred and no mispick condition was sensed by the Loader. The Original Clupickers were sufficiently close together that even if one or two mispicks

occurred the plies were still separated, and the Loader still functioned normally. So, although the Original Clupickers were performing poorly, the Clupickers' performance was not impacting the Loader's performance.

On separating the Original Clupickers, in preparation for the designed experiment, deficiencies in the Original Clupicker setup immediately surfaced. Using the White bundles as diagnostic tools, several Clupicker and Loader misadjustments surfaced. The first misadjustment involved the "Arm Pressure, Compression Spring".[2.4] The first diagnostic run (see Appendix E) clearly showed that doublepicks were the primary form of mispicks. Doublepicks can occur for several reasons, but one of the reasons is excessive downward pressure by the Picker Wheel on the top ply. Reducing the Compression Spring tensions dramatically improved the Original Pickers' performances but did not completely eliminate the doublepicking tendencies of Original Picker number four (again, see Appendix E).

During the first diagnostic run it was observed that all of the Clupickers were bouncing on the surface of the test bundles. During the pick cycle, as the Bimba Cylinders rotated the Picker Actuating Shafts[2.5], the Clupickers were hitting the compliant bundle surfaces and bouncing in much the same way as a basketball dropped from a fraction of an inch bounces on a hardwood floor. The bouncing occurred quickly and was difficult to isolate, but the bouncing condition explained why the Compression Spring pressures were set so high. Increasing the Compression Spring tensions decreased the bounce condition minimizing the chances that the pickers would pick while the picker wheels were not in contact with the top plies. Unfortunately, increasing the Compression Spring pressure is a double edged sword. Increasing the Compression Spring pressure may minimize mispicks, but increasing the Compression Spring pressure increases the chance of doublepicks.

The only way to approach the bouncing problem was to reduce the speed at which the Bimba Cylinders rotated the Picker Actuating Shafts. Adjusting the check valves connected to the Bimba Cylinders, allowed all of the Clupickers to engage the top plies without bouncing and with plenty of time to grasp and lift the plies before the shutter advance., Subsequent diagnostic tests (the results of which were not formerly recorded) showed that picker performance improved, but was still well below the 99.5% and 99.9% performance levels discussed by Dr. Tim Clapp.

Using the Loader's Manual Run feature[2.6], it was possible to cycle through the entire pick and place process and closely observe the Clupicker/Hold-down Finger Interaction. Close inspection showed that all of the Modified Clupickers were adjusted according to the instructions shown in Figure 11 of the Loader manual. On the Original Clupicker side, however, Hold-down Finger Number Five was well outside of Clupicker Number Five's Picker

Frame, while Hold-down Finger Number Four was actually striking Clupicker Number Four's Picker Frame during the pick operation. Closer inspection also showed that none of the Hold-down Fingers were adjusted to the same bundle depth. In other words, some of the Hold-down Fingers came out further from their Hold-down Finger Assemblies than others affecting the Clupickers' bundle misalignment sensitivity. The further out the Hold-down Fingers are, the less sensitive to ply misalignment the Clupickers are. Unfortunately, the further out the Hold-down Fingers are, the more likely the occurrence of mispicks due to plies failing to clear the Hold-down Fingers.

Assumption that Clupickers are Properly Maintained is False

In conversations with Elroy Pierce and Bob Bennett, the two sewing mechanics responsible for maintaining the machines on CAR's Demo floor, two points were brought out. First, all of the original Pick-linkage Compression Springs on the Modified Clupicker had broken and had had to be replaced. Second, beyond replacing the Compression Springs, no other adjustments had been made to the Loader or Clupickers since the Jet Sew technician had installed the Modified Pickers.

All of the adjustments that had to be made to the Clupickers clearly showed that the Clupickers were neither properly setup nor properly maintained, and as mentioned earlier, close Clupicker spacing prevented poor Clupicker performance from being noted. In any event, the experimental assumptions of proper machine setup and maintenance were wrong. Other experimental assumptions, that were quickly dismissed, all supported the idea that with minimum effort experimental bundles could be reused.

Assumption that Bundle Reuse is Simple Proves False

The single assumption that reusing bundles would be simple was based on a number of supporting assumptions.

First, the experimental team assumed that destacking the shirt sleeves would not damage the sleeves. The initial test runs (Appendix D) clearly showed that the second run with the Chambray bundles produced poorer results than the first run. Repeated runs with the White bundles also showed that the fabric tended to fray, and that tangling of the frayed edges led to increased Clupicker errors.

A second supporting assumption which proved grossly in error was the assumption that the Loader's alignment system could accurately realign the plies. Carefully loaded bundles with near perfectly aligned edges would be picked at the front end of the Loader. Bundles with large variations (up to 3/4" misalignment) would be deposited on the back end of the Loader. It

became apparent that although some ply misalignment was the result of fabric characteristics (such as lubricity), the majority of ply alignment variation could be contributed to the Loader itself.

A third assumption that was immediately challenged was the assumption that any ply alignment errors that occurred during the pick-and-placement process could be corrected manually. Careful observation of the Hold-down Fingers showed that even carefully aligned bundles frequently had plies which the Fingers failed to grasp. This condition, coupled with the time it took to manually realign the stacks coming off the loader, made it clear that the time spent realigning all of the plies within the test bundles would greatly outweigh the time it took to spread, cut, and organize entirely new bundles. This was a serious concern for the test team because all of the diagnostic tests had consumed more than five of the seven days of time allotted for conducting the original experiment. What was needed was a way to quickly tidy up the misaligned plies coming off of the Loader.

Bologna Slicer Needed to Solve Some of the Problems

Tests with the White bundles had shown that even freshly cut bundles were highly susceptible to ply misalignment errors. What was needed was a way to collect, align, and place test bundles so that ply misalignment was minimized and testing throughput was maximized. CAR's answer to the ply misalignment problem was dubbed "The Bologna Slicer".

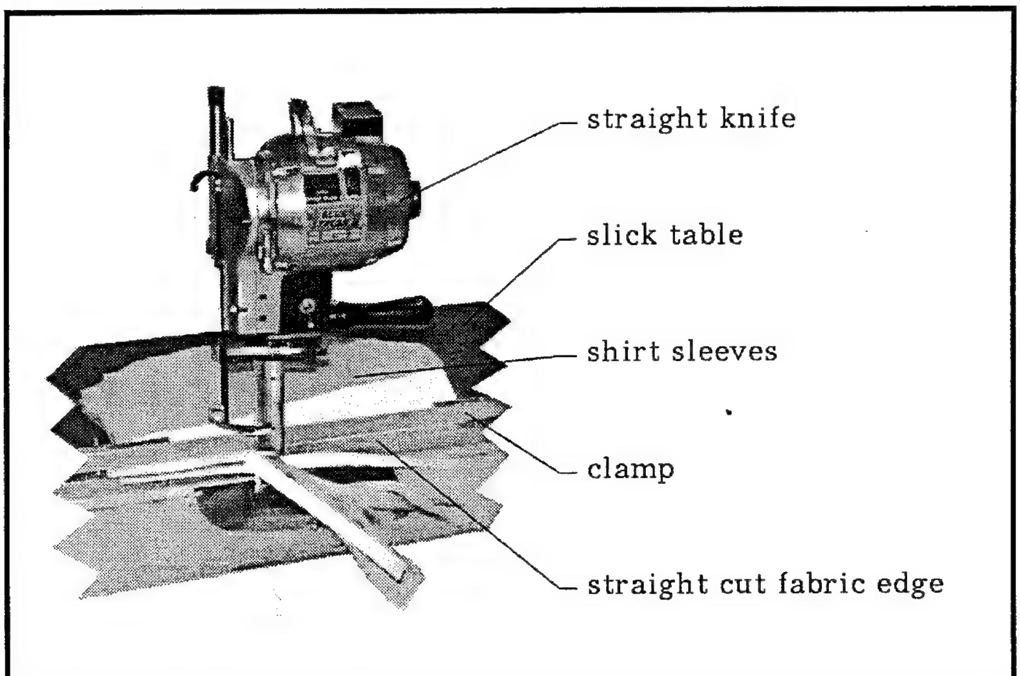

Figure 2-1: Bologna Slicer

The Bologna Slicer consisted of four basic parts; a slick table surface, pieces of cardboard to sandwich the bundle being cut, a large custom clamp/guide, and an Eastman Blue Streak II Reciprocating Straight Knife.

The Bologna Slicer worked as follows. First, a reasonably neat bundle of fabric was sandwiched between the two pieces of cardboard. The cardboard/fabric bundle was then set on the slick table, and clamped in the custom clamp/guide. The custom clamp/guide, consisting of two pieces of channel iron and two long screws, was then used to clamp the cardboard/fabric bundle.

The clamp/guide was designed to run between the edge of the slick table and the cutting blade of the straight knife. The straight knife was fixed relative to the slick table edge. After the straight knife was sharpened, lubricated, and left to run, the clamp/guide (cardboard, fabric and all) was pushed along the slick table. As the clamp/guide was pushed, the straight knife carved off any excess material hanging beyond the edge of the clamp/guide. The knife was then turned off, the clamp was released, and the bundle, with its perfectly straight, string-free edge, was transported on the rigid cardboard to the Loader. The entire process allowed uneven processed bundles to have perfectly aligned edges even after being placed on the Loader.

The downside of reforming the bundle edges was that fabric was progressively removed from the sleeves so that they became smaller and smaller. To ensure that the process was completely randomized, and therefore had the same impact on both the Original and Modified Clupicker banks, the bundle positions were switched after each run. This ensured that the bundle first processed on the Original Clupicker side of the machine was then processed on the Modified Clupicker side of the machine. Randomizing the process ensured that any detrimental impact of reshaping the sleeves was equally distributed among both of the Clupicker banks.

Experimental Time Constraints Reduce Flexibility

The Bologna Slicer ensured that any bundles disturbed by the Loader could be quickly reprocessed and reused by the Loader. The Bologna Slicer also ensured that more of the time remaining could be used to test Clupickers than prepare additional test samples. Unfortunately, a large portion of the time designated for testing had now been consumed in pre-testing preparation, and despite the pre-test preparation, it was still difficult to cope with a number of original experimental assumptions.

Remaining Assumptions Challenged

Because CAR does not have a controlled environment, there was no way of knowing if the initial Clupicker/Loader setup matched Dr. Tim Clapp's setup in which he produced the 99.5+% and 99.9% Clupicker performance benchmarks.

Diagnostic experiments made it clear that a much larger portion of time would be spent preparing, loading, unloading, and repreparing the test bundles than actually running the Clupickers.

The test team concluded, based on initial setup, that the half day allotted for side-to-side change-over was too little time. Originally, the designed experiment was to include a side-to-side change-over between each day's processing. Given the slow progress made during initial setup, and the overall sensitivity of the Clupickers and Loader to minor influences, the test team decided to abandon the original experiment's call for daily side-to-side change-overs.

New Experimental Approach Developed

The inability to randomize side-to-side Loader affects, along with overwhelming evidence that a large number original assumptions were insupportable, led to questions about the reliability of the original experimental design. Recognizing the difficulties encounted in designing the original experiment, and recognizing that time was too limited to design another experiment, a new test approach was developed. The new approach was based on a multi-test process (instead of the original single-experiment design). The approach was as follows:

1. Conduct a series of informal diagnostic test to make sure the Clupicker performance is as good as reasonably possible.
2. Benchmark, or calibrate, the Clupickers' performances using a simple pre-experimental calibration test.
3. Using the original experiment's sleeve samples, conduct a new experiment on the Clupickers.
4. Conduct a post-experimental calibration test(s) to see if the Clupickers' performances changed during Step 3.
5. Use the pre- and post-experimental calibration data to create correction factors for the actual experimental data collected in Step 3.
6. Draw conclusions based on Step 3 and Step 5 data.

Diagnostic Tests

Using the Bologna Slicer (described above), and bundles of oxford cloth short sleeves, CAR conducted an extensive series of diagnostic tests. The purpose

of the test was to tune the Clupickers' performances to the highest values reasonably possible. Appendix E shows the data collected from some of the initial diagnostic tests. In the end, however, recording data interfered with adjusting the Clupickers and no additional data was taken. Once the Clupickers were performing reasonably well, the test team began the pre-experimental calibration test.

Pre-experimental Calibration Test - (Correction Factor 1)

As explained in the previous section, Step Two of the Clupicker Test involved running a simple test to benchmark (calibrate) the Clupickers' performances. In Step One, diagnostic tests had been performed using bundles made of white oxford cloth. Useful as a diagnostic tool, new bundles of white oxford cloth were prepared for use as a calibration tool.

As before, the bundles were completely randomized and divided into two equal stacks. These stacks were processed by the Loader, realigned using the Bologna Slicer, switched from one side of the Loader to the other, and reprocessed by the Loader until 1000 plies had been processed by both the Original and Modified Clupickers. The data collected during this process are given in Appendix F.

In processing 1000 Army AG 415 short-sleeves, each of the Original Clupickers mispicked once, and each of the mispicks were on completely different plies. This information could be used to imply individual Original Clupicker performances of 99.9%. The Modified Clupickers had no mispicks at all, implying a performance level of 100%.

Obviously, claiming the Modified Clupickers were 100% efficient is ridiculous. Such a claim is ridiculous because only one type of fabric was used and only a limited number of plies were processed. Since no one knows whether the white oxford cloth is representative of all shirting fabrics, the pre-experimental calibration-test results can not be used to make performance estimates on all shirting fabrics. The pre-experimental calibration test did confirm, however, that the Original Clupickers were working as well as could be expected. As Robert Keith Daniel's and Dr. Tim Clapp's industry survey points out, the 99.9% Original Clupicker performance level was well above the Apparel Industry's production efficiency expectations[2.7].

Description of the Actual Experiment

Once the pre-experimental calibration test had been run, the original experimental bundles were processed. The method used to process the experimental bundles was exactly the same as the method used to process the calibration bundles. As explained in the "Pre-experimental Setup" section, the bundles were completely randomized and divided into two equal

stacks. These stacks were processed by the Loader, realigned using the Bologna Slicer, switched from one side of the Loader to the other, and reprocessed by the Loader.

In formally designed experiments, calculating the number of plies to be processed is a function of expected experimental sensitivity. In the original designed experiment 16,000 plies were deemed necessary in order to identify and separate mispicks caused by influences other than Clupicker performance. By processing 16,000 plies, the test team could say with 90% certainty that the Modified Clupickers outperformed the Original Clupickers, based on expected performances of 99.9% and 99.5+%, respectively.

However, since the original experiment had been scrapped, and the production floor needed access to the Loader, it was arbitrarily decided that each of the experimental bundles should be processed a minimum of five times, at which point the data would be inspected for trends. Processing the experimental bundles five times each would be equivalent to processing over 2000 plies per group of Clupickers. If, after processing 2000+ plies per Clupicker group, no clear trends were established, additional processing would take place. Based on diagnostic test results, however, the test team felt that processing 2000 + plies, and adding corrections from pre- and post-experimental calibration tests would provide adequate information for drawing firm conclusions about the relative performance of the Modified Clupickers versus the Original Clupickers.

Experimental Results

Using two bundles of each of the bundle types (see Appendix C) CAR began the Clupicker experiment. Test results are given in Appendix G. Summary results are listed below. To understand the results, it is important to understand the difference between Total Pick Errors and Group Picker Errors. Total Pick Errors are the sum of all the mispicks and doublepicks for each individual Clupicker. Group Picker Errors are the total number of mispicks and doublepicks on a Clupicker group basis. For example: If Original Clupickers 5 and 6 both mispicked when trying to pick up a particular ply, the total number of pick errors would be two (2). The Original Clupicker group (made of Pickers 4, 5, and 6) would have an error count of one (1). In other words, Clupickers 4, 5, and 6, as a group, failed to pick up the ply, hence an error count of one (1) is assigned to the of Original Clupickers. The reasons for evaluating the data this way, and the effect it has on Clupicker performance evaluations is discussed in detail in the "Final Data Evaluation" section.

Table 2-1: Bundle Number One's Performance (Chambray/Chambray) 315 Plies Processed/Clupicker Group				
Clupicker #'s	Mispicks	Doublepicks	Individual Picker Errors	Group Picker Errors
Original				
6	1	2	3	10
5	4	3	7	
4	2		2	
		Totals	12	10
Modified				
3	0	0	0	0
2	0	0	0	
1	0	0	0	
		Totals	0	0

Table 2-2: Bundle Number Two's Performance (Dark Blue Broad Cloth/Wendy's Striped Cloth) 840 Plies Processed/Clupicker Group				
Clupicker #'s	Mispicks	Doublepicks	Individual Picker Errors	Group Picker Errors
Original				
6	29	1	30	46
5	9	2	11	
4	25	1	26	
		Totals	67	46
Modified				
3	6	2	8	22
2	10	0	10	
1	14	1	15	
		Totals	33	22

Table 2-3: Bundle Number Three's Performance (Pink Oxford Cloth/White Oxford Cloth) 960 Plies Processed/Clupicker Group				
Clupicker #'s	Mispicks	Doublepicks	Individual Picker Errors	Group Picker Errors
Original				
6	19	5	24	75
5	3	21	24	
4	34	17	51	
		Totals	99	75
Modified				
3	4	4	8	25
2	20	2	22	
1	6	2	8	
		Totals	38	25

Table 2-4: Bundle Number Four's Performance (Blue Striped Oxford/Yellow Oxford) 129 Plies Processed/Clupicker Group				
Clupicker #'s	Mispicks	Doublepicks	Individual Picker Errors	Group Picker Errors
Original				
6	4	3	7	34
5	2	12	14	
4	13	2	15	
		Totals	36	34
Modified				
3	1	0	1	16
2	15	0	15	
1	5	1	6	
		Totals	22	16

A complete summary of the contents in Tables 2-1 through 2-4 is given in Table 2-5 on the next page.

Table 2-5: Summary of Tables 2-1 through 2-4 2,760 Plies Processed/Clupicker Group				
Clupicker #'s	Mispicks	Doublepicks	Individual Picker Errors	Group Picker Errors
Original				
6	53	11	64	165
5	18	38	56	
4	74	20	94	
		Totals	214	165
Modified				
3	17	6	23	63
2	45	12	57	
1	25	4	29	
		Totals	109	63

Before any reasonable conclusions could be drawn from this data, a post-experimental calibration test had to be conducted.

Post-experimental Calibration Test "A"

Once the Clupicker experiment had been run, a post-experimental calibration test was conducted. This test was performed to see if the Original Clupickers' performances had changed over the duration of the actual Clupicker experiment. (Based on the fact that during the actual experiment the Modified Clupickers had clearly outperformed the Original Clupickers, the Modified Clupickers were not retested.) As with the pre-experimental calibration test, white oxford cloth was used to conduct the test. In fact, to avoid the possibility of introducing fabric related errors, the same bundles of white oxford cloth sleeves were used.

Throughout all the experiments great care was taken to minimize the distortion caused by use of the Bologna Slicer. To ensure that reusing the pre-experimental sleeves would not introduce significant errors in post-experimental calibration test, the test team looked at the experimental data to see if significant changes in Clupicker performance had occurred as the bundles were reused. An informal evaluation concluded that reusing the pre-experimental sleeves would have a less significant affect on Clupicker performance than using a completely new set of sleeves cut from a different roll of white oxford cloth. With this decision made, the test team proceeded with the post-experimental calibration test of the Original Clupickers.

Again the method used to process the post-experimental calibration bundles was exactly the same as the method used to process the pre-

experimental calibration bundles. These stacks were processed by the Original Clupickers located on the left-hand-side of the Loader, realigned using the Bologna Slicer, and reprocessed by the Loader.

Results of the post-experimental calibration test are given in Appendix H. As the test progressed, the white oxford sleeves became shorter and shorter as a result of using the Bologna Slicer to recondition the bundle edges. It was noted during the experiment that a large number of mispicks were accompanied by Hold-down Finger related errors. Hold-down Finger errors occurred when any Finger failed to contact and stabilize a ply before the ply was picked. Since the bundles were getting progressively narrower the test team postulates that the sleeve bundles were losing stability. The reduction in bundle stability may have caused the bundles to distort more readily, leading to ply misalignment, Hold-down Finger errors, and associated mispicks.

In any event, after picking 1000 plies, all but one of the thirteen mispicks that occurred on the Original Clupicker side of the Loader was counted as a legitimate error (even though fabric misalignment was suspected as a contributing factor in all of the errors). In picking 1000 plies only Clupicker 5 produced pick errors, and there were at least 12 errors in the post-calibration test versus one (1) error in the pre-calibration test. The only conclusion which could be drawn with certainty was the fact that during the experiment something affected Clupicker 5's performance. What the test team did not know was whether Clupicker 5's performance had any detrimental affects on Original Clupickers 4 and 6. The test team decided to conduct an additional test to see if Clupicker 5's failure to pick would have had any affect on Clupickers 4 and 6.

Post-experimental Calibration Test "B"

As explained in the previous section, Post-experimental Calibration Test B was performed to see if Clupicker 5's failure to pick had any affect on Clupickers 4 and 6. Just as in previous calibration tests, only the Original Clupickers were tested. Clupicker 5 was turned off using the on/off switch located on the front of the Loader control panel allowing Clupickers 4 and 6 to function normally.

Once again white oxford cloth was used to conduct the test. Partly out of curiosity, and mainly out of a need to save time, the same white oxford cloth sleeves were used, yet again. Although the sleeves still resembled the original Army AG 415 sleeves, the sleeves were now a good three inches (25%) shorter. In fact, after reprocessing four more times, the test team decided to discontinue the experiment short of the 1000 ply limit used in both the pre- and post-experimental calibration test.

Results of the test are given in Appendix H. After picking 875 plies, the test team decided to discontinue the test because the sleeves had become sufficiently short that some of the Hold Down Bumpers on the orientation end of the Loader had started to miss the sleeves and were scuffing the Loaders' Shutter. In 875 picks, only two mispicks occurred, both involving Clupicker 6. The test showed, however, that if any interaction had occurred between Clupicker 5 and the other Original Clupickers, the interactions were weak at best. In other words, this test showed that as Clupicker 5's performance degenerated it probably had little affect on the other Original Clupickers (4 and 6).

Final Data Evaluation

The test team now had the following information:

1. Data showing that the initial Loader setup was reasonably good (Appendix F).

2. Data comparing the performance of the Original Clupickers to the Modified Clupickers over a broad range of continuously changing fabrics (Appendix G).

3. Data showing that Clupicker 5's performance had deteriorated during the experiment, and that mispicks caused by Clupicker 5 should not be considered in the final Clupicker performance evaluation (Appendix H).

4. Data showing that Clupicker 5's poor performance had little if any affect on the other Original Clupickers (Appendix H).

Data Evaluation - No Correction Factors

All of the data collected in the pre- and post-experimental tests was collected to ensure that the Modified Clupickers were not given a performance edge over the Original Clupickers. The original experimental design had ensured that testing was unbiased, but as discussed, the original experiment was based on a number of assumptions which, though reasonable at the time, proved insupportable. In the end, all of the data collected could be used to provide correction factors favoring the performance of the Original Clupickers, however.

Without any correction factors, the Clupicker performance data of Appendix G and Table 2-5 could be condensed into the following table:

Table 2-6: Clupicker Performance Data (Derived from Appendix G) No Correction Factors 2,760 Plies Processed/Clupicker Group					
Clupicker #'s	Mispicks	Doublepicks	Total Pick Errors	Individual Picker Performance	Group Picker Performance See Table 2-5
Original					
6	53	11	64	97.68	94.02^B
5	18	38	56	97.97	
4	74	20	94	96.59	
Individual Clupicker Performance Average				97.41^A	97.97^C
No Correction Factors				97.41	97.97
Modified					
3	17	6	23	99.17	97.72^B
2	45	12	57	97.93	
1	25	4	29	98.95	
Individual Clupicker Performance Average				98.68^A	99.23^C

Looking at the Total Pick Errors for the individual Clupickers one could conclude that the Original Clupicker design had 214 mispicks out of 2,760 plies. This equates to a 92.25%[2.8] picking performance. Using the same logic one might also conclude that the Modified Clupickers had a performance rating of 96.05% . These performance ratings are misleading, however. The reason these performance ratings are misleading is that they are actually the performance ratings of the three Original Clupickers combined, not the average performance ratings of the individual Clupickers.

[A] To calculate the average performance rating of a single type of Clupicker one must first calculate the picking performance of each individual Clupicker, of a specific type, and then average the results together. Using this approach Clupicker 6's average performance was calculated as follows:

$$\text{Clupicker Performance}_{\text{Picker 6}} = \frac{2{,}760 \text{ plies}_{\text{picked}} - 64 \text{ plies}_{\text{mispicked}}}{2{,}760 \text{ plies}_{\text{picked}}}$$

$$= 0.9768$$

$$= 97.68\% \qquad (2.1)$$

Performing the same calculation for the other Clupickers yields: Clupicker 5 = 97.97%, Clupicker 4 = 96.59%, Clupicker 3 = 99.17%, Clupicker 2 = 97.93%, and Clupicker 1 = 98.95%. Averaging the Original Clupicker performances gives a performance rating of 97.41% (below Dr. Clapp's 99.5+% rating). Averaging the Modified Clupicker performances gives a performance rating of 98.68% (also below Dr. Clapp's 99.9% rating, but not by much). These average performance ratings are not conclusive, however, because there are other justifiable ways of looking at the data.

[B] In collecting the mispick/doublepick data used in the above calculations ([A]) it was assumed that the Clupickers had no influence on each other. For example, if Clupicker 5 mispicked it was assumed to have no affect on Clupickers 4 and/or 6. In experimental terms, it was assumed that during the picking process there were no interactions taking place between the individual Clupickers in the same group. (No interactions could occur between the Original and Modified Clupicker groups because they were picking from separate bundles.)

If one assumes interactions were taking place between the Clupickers within each group, the mispick data is slightly different. For example, based on the assumption that there were strong interactions between the Clupickers, if Clupicker 5 and 6 mispicked one might assume that one of the mispicks was caused by the other mispick. Based on this assumption, the two mispicks would only be counted as one mispick.

Evaluating Appendix G on the assumption that strong device interactions were taking place yielded Table 2-5 (shown again for convenience).

Table 2-5: Summary of Table 2-1 through 2-4
2,760 Plies Processed/Clupicker Group

Clupicker #'s	Mispicks	Doublepicks	Individual Picker Errors	Group Picker Errors
Original				
6	53	11	64	165
5	18	38	56	
4	74	20	94	
		Totals	214	165
Modified				
3	17	6	23	63
2	45	12	57	
1	25	4	29	
		Totals	109	63

Note the difference between the total number of individual picker errors, and the total number of group picker errors. The differences are a direct consequence of the assumption that for individual pickers no device interactions are taking place, while under the group picker heading strong interactions are taking place.

Using the total number of group picker errors as a starting point, the group picker performance is calculated as follows:

$$\text{Original Clupicker Performance}_{\text{Group}} = \frac{2{,}760 \text{ plies}_{\text{picked}} - 165 \text{ plies}_{\text{mispicked}}}{2{,}760 \text{ plies}_{\text{picked}}}$$

$$= 0.9402$$

$$= 94.02\% \tag{2.2}$$

Using the same approach on the Modified Clupicker group data yields a Modified Clupicker group performance of 97.72%.

[c] To calculate individual Clupicker performances from the group picker data requires working backwards from the group performance data. Using the Original Clupicker group performance value of 94.02%, the calculation is as follows:

$$\text{Clupicker Performance}_{\text{Individual}} = (\text{Clupicker Performance}_{\text{Group}})^{1/3}$$

$$= (0.9402)^{0.333}$$

$$= 0.9797$$

$$= 97.97\% \tag{2.3}$$

To verify that this calculation is reasonable, calculate the Original Clupicker group performance from the Original Clupicker individual performance using the following equation:

$$\text{Clupicker Performance}_{\text{Group}} = (\text{Clupicker Performance}_{\text{Individual}})^{3} \tag{2.4}$$

The reason the individual Clupicker performance value is raised to the power of three (3) is that the group Clupicker performance is the product of all of the individual Clupicker performances within the group, in this case three (3) Clupickers.

To calculate the individual Modified Clupicker performance use Equation 2.3 with the Modified Clupicker group performance value of 97.72%. Equation 2.3 yields an individual Modified Clupicker performance value of 99.23%.

Data Evaluation - With Correction Factors

As discussed in detail at the beginning of this report, experimental assumptions can make or break an experiment. Although not explicitly stated, all the results calculated above, assume that at the start of the experiment all of the Clupickers were performing equally well. Appendix F clearly shows that the Modified Clupickers were picking white oxford cloth better than the Original Clupickers and, as a result, *might* have had a performance advantage.

The results also assume that for the duration of the experiment the picker performances did not degrade. Appendix H shows that Clupicker 5's performance degraded substantially. Averaging Clupicker 5's poor performance in with the other Original Clupickers lowers the Original Clupicker's performance rating.

The individual Clupicker performance values and the group Clupicker performance values also assume no Clupicker interactions, and strong Clupicker interaction, respectively. Appendix H *seems* to support the hypothesis that no Clupicker interactions were taking place, but no tests were done to see whether the failure of two pickers within a Clupicker group led to mispicks of the third picker within the group. In other words, *no experiments were done to determine if weak interactions exist between the Clupickers within a group.*

Addressing the issue of weak Clupicker interaction may not be worthwhile, however. The reason for this is that Clupicker interaction is most likely a function of the distances separating Clupickers within a group, and a function of the weight of the individual plies being picked. Since these parameters are affected by the dimensions of the fabric pieces being picked, weak interactions are sensitive not only to fabric type, which is hard to quantify, but piece shape as well.

As mentioned in the "Experimental Setup" section of this document, the Original Clupickers were so closely spaced that during normal demonstration and production runs, no significant performance problems were detected. In the actual experiment, the Clupickers were spaced

further apart, but Appendix H shows that even with Clupicker 5 turned off, Clupickers 4 and 6 performed adequately. If the Clupickers within each group had been spaced even farther apart, and heavier plies had been used (for example if three Clupickers had been used to pick large shirt fronts instead of short shirt sleeves) it is likely that device interactions would have come into play.

The issue of device interactions will be left to future exploration, however. Suffice it to say, the data presented above covers the two extreme cases, that of no Clupicker interactions (based on individual Clupicker performances) and that of strong Clupicker interactions (based on group Clupicker performances). The data presented in the next sections will address other experimental assumptions.

Correction Factor 1

Another way of looking at the original data is as follows:

Table 2-7: Clupicker Performance Data
With Pre-experimental Correction[D]
(i.e. Correction Factor 1, Derived from Appendix F)
2,760 Plies Processed/Clupicker Group

Clupicker #'s	Mispicks	Doublepicks	Total Pick Errors	Individual Picker Performance	Group Picker Performance See Table 2-5
Original					
6	53	11	64	97.68	94.02
5	18	38	56	97.97	
4	74	20	94	96.59	
Individual Clupicker Performance Average				97.41	97.97
Correction Factor = 1.001[E]				97.51[F]	98.06[G]
Modified					
3	17	6	23	99.17	97.72
2	45	12	57	97.93	
1	25	4	29	98,95	
Individual Clupicker Performance Average				98.68	99.23

[D] This data makes the same assumptions that were made in Table 2-6 except this data accounts for the fact that at the start of the experiment the Original Clupickers were not picking white oxford cloth as well as the Modified Clupickers. White oxford cloth was chosen as a benchmark fabric because it is reasonably representative of shirting materials in general. While this assumption is contestable, it would be difficult to provide a

justifiably better alternative, and the calibration test had to start somewhere.

Assuming then, that white oxford cloth was a good calibration material, and that the Clupickers' individual performances were not affected by the other Clupickers, Appendix F implies that at the start of the experiment Clupicker 6 had one mispick in 1000 plies which equals a performance of 99.9%. The same holds true for Clupickers 5 and 4. This gives the Original Clupickers an individual performance average of 99.9%. Clupickers 3, 2, and 1 had 100% performance levels giving the Modified Clupickers an individual performance average of 100%.

While these performance averages are obviously high, they are high because they do not represent Clupicker performance for all fabrics. These performance averages represent the performance of the Clupickers on a small sample of fabric (1000 plies of white oxford cloth). Again, white oxford cloth was selected because it is difficult to provide a justifiably better alternative to represent the larger population of shirting fabrics in general, and because the pre-experimental correction had to start somewhere.

[E] Using the Original Clupicker performance from Appendix F, the following calculation can be used to determine a calibration factor:

$$\begin{aligned}\text{Correction Factor} &= (\text{Clupicker Performance}_{\text{Original}})^{-1} \\ &= (99.90\%)^{-1} \\ &= (0.9990)^{-1} \\ &= 1.001 \end{aligned} \tag{2.5}$$

By using this correction factor (called Correction Factor 1, or C.F. 1) the Original Clupicker performance at the start of the experiment can be made to match the Modified Clupicker performance at the start of the experiment.

$$\begin{aligned}\text{Clupicker Performance}_{\text{Modified}} &= \text{Clupicker Performance}_{\text{Original}} \times \text{C.F. 1} \\ 100\% &= 99.90\% \times 1.001 \\ 100\% &= 100\% \quad \surd \end{aligned} \tag{2.6}$$

[F,G] Using Equation 2.6 and substituting individual Clupicker performance averages based on individual and group performance values yields a

corrected Original Clupicker Performance of 97.51% and a corrected Modified Clupicker Performance of 98.06%.

At this point it is important to note the following:

1. Correction Factor 1 was derived from individual Clupicker performance data, not from group Clupicker performance data. Appendix F shows that during the calibration test none of the Clupickers mispicked simultaneously so the individual and group performance data would have been the same anyway.

2. Since an underlying concern at the start of the experiment was that the Original Clupickers were at a disadvantage to the Modified Clupickers, Correction Factor 1 favors the Original Clupickers.

Correction Factor 2

Correction Factor 1 takes into account the fact the at the start of the experiment the Original Clupickers were not picking as well as the Modified Clupickers. Correction Factor 2 takes into account the fact that during the experiment Clupicker 5's performance degraded. Correction Factor 2 was derived from the test results shown in Appendix H.

Appendix H clearly shows that, following the actual experiment, Clupicker 5's performance was well below its performance level before the experiment (as shown in Appendix F). To test whether Clupicker 5's poor performance had any affect on Clupickers 4 and 6, Clupicker 5 was turned off, and Clupickers 4 and 6 were made to repick the same material used to obtain the data in Appendix H test. The results of the test are shown in Appendix H - Test 2, and are discussed in the "Post-experimental Calibration-Test B" section presented earlier in this document.

As a result of these tests, the test team decided to exclude all data pertaining to Clupicker 5 from the experimental results shown in Table 2-5. The resulting table (Table 2-8) is shown on the next page.

Table 2-8: Similar to Table 2-5 Minus The Influence of Clupicker 5 2,760 Plies Processed/Clupicker Group				
Clupicker #'s	Mispicks	Doublepicks	Individual Picker Errors	Group Picker Errors
Original				
6	53	11	64	109
5	—	—	—	
4	74	20	94	
		Totals	158	109
Modified				
3	17	6	23	63
2	45	12	57	
1	25	4	29	
		Totals	109	63

Using Equations 2.1 through 2.4, Table 2-8 can be converted into Table 2-9, below:

Table 2-9: Clupicker Performance Data With Post-experimental Correction (i.e. Correction Factor 2, Derived from Appendix H) 2,760 Plies Processed/Clupicker Group					
Clupicker #'s	Mispicks	Doublepicks	Total Pick Errors	Individual Picker Performance	Group Picker Performance See Table 2-8
Original					
6	53	11	64	97.68	96.05
5	—	—	—	—	
4	74	20	94	96.59	
Individual Clupicker Performance without any Correction Factors (From Table 2-6)				97.41	97.97
Individual Clupicker Performance with Correction Factor 2				97.14	98.67
Modified					
3	17	6	23	99.17	97.72
2	45	12	57	97.93	
1	25	4	29	98.95	
Individual Clupicker Performance Average				98.68	99.23

In light of the individual Original Clupicker performance values calculated using Correction Factor 2, it is difficult to say whether Clupicker 5's performance did indeed degenerated over the course of the experiment. Assuming no device interactions, the individual Clupicker performance calculated without correction factors is higher (97.41%) than the individual Clupicker performance calculated with Correction Factor 2 (97.14%). This implies that Clupicker 5's performance was not poor at all. On the other hand, assuming device interactions were taking place, the individual Clupicker performance calculated without correction factors is lower (97.97%) than the individual Clupicker performance calculated with Correction Factor 2 (98.67%).

This puzzle will be left alone since the purpose of the data analysis was to ensure that the Modified Clupickers did not have an unfair performance advantage over the Original Clupickers. As long as the maximum Original Clupicker values are used, any subsequent performance comparisons will be conservative. Conservative results ensure that if performance variations do appear, it can be assumed that performance variations do exist.

Correction Factors 1 + 2

To ensure that the Modified Clupickers had no unfair advantage over the Original Clupicker, Table 2-10 (on the next page) was constructed applying Correction Factors 1 and 2.

Table 2-10: Clupicker Performance Data (Based on Table 2-9) With Pre- and Post-experimental Correction 2,760 Plies Processed/Clupicker Group					
Clupicker #'s	Mispicks	Doublepicks	Total Pick Errors	Individual Picker Performance	Group Picker Performance
Original					
6	53	11	64	97.68	96.05
5	—	—	—	—	
4	74	20	94	96.59	
Individual Clupicker Performance without any Correction Factors (From Table 2-6)				97.41	97.97
Individual Clupicker Performance with Correction Factors 1 and 2				97.23	98.76
Modified					
3	17	6	23	99.17	97.72
2	45	12	57	97.93	
1	25	4	29	98.95	
Individual Clupicker Performance Average				98.68	99.23

Data Evaluation - Summary

The following table condenses all of the information from Tables 2-6, 2-7, 2-9, and 2-10.

Table 2-11: Clupicker Performance Data Summary (See Tables 2-6, -7, -9, and -10)			
Clupicker Type	Correction Factors	Individual Picker Performance	
		No Clupicker Interaction	Strong Clupicker Interaction
Original	None	97.41	97.97
	1	**97.51***	98.06
	2	97.14	98.67
	1 and 2	97.23	**98.76**
Modified	None	**98.68**	**99.23**
* Values in bold are the highest values for each Clupicker type.			

From Table 2-11 one can conclude that regardless of whether correction factors are applied or whether device interactions are present or not:

For shirting fabrics in general, the Modified Clupickers consistently outperform the Original Clupickers.

Remaining Questions

Several key questions remain to be answered, however.

1. Are the performance improvements shown above sufficient to justify replacing Original Clupickers with Modified Clupickers?

2. Are the Clupicker performances, shown above, sufficient to justify investing in Clupicker technology at all?

3. What other factors influence the decision to replace the Original Clupickers with the Modified Clupickers?

4. Are there other factors which have a greater influence on Clupicker performance than the features incorporated into the Modified Clupicker?

5. Are there other improvements which could make the Loader/Clupicker technology better, i.e. more financially attractive?

These questions are answered at the end of Chapter 4.

Inter-Office Memorandum

Date:

To:

Reference:

From:

3

Chapter 3 - Production Model of a Jet Sew Hemmer

Need for a Time-based Production Model

Answering the questions raised at the end of Chapter 2 requires conducting a cost analysis based on the Clupicker performance levels. Completing a comprehensive cost analysis requires understanding how Clupickers affect manufacturing. Before one can determine how Clupickers affect manufacturing, however, one must first understand how Clupickers affect their related manufacturing operation.

Clupickers are subcomponents of Jet Sew Loaders. In many shirt manufacturing facilities (including CAR) Jet Sew 5000 Class Automatic Loaders are attached to Jet Sew Centerplaite/Sleeve Hemmers. The Clupickers only pick when the Hemmers ask the Loaders for more parts. This means that the action of the Clupickers is governed by the Hemmers.

According to Charlotte Pierce, who is responsible for CAR's Demo Floor operations, the Jet Sew Automatic Hemmer, sewing 12 stitches per inch and running continuously and flawlessly, can process 4,500 medium men's right fronts in eight hours. This means the Hemmer can process approximately one front every 6.5 seconds. Clupickers alone can be made to cycle much faster than once every six seconds, and Loaders can be made to cycle faster as well. The key is to recognize that the Hemmer sets the pace at which the Clupickers operate. Therefore, to understand how Clupickers affect manufacturing, one must understand how Jet Sew Hemmers fits into apparel manufacturing environments.

All manufacturing (including apparel) takes time. Manufacturing time can be broken into three distinct categories: direct labor, machine, and indirect labor. The direct labor time, machine time, and indirect labor time is spent performing direct labor, machine, and indirect labor operations, respectively. To understand how much time a manufacturing operation takes, one must first understand what direct labor, machine, and indirect labor operations are involved and how these operations are interrelated. In other words, one must develop a time-based production model. To develop a time-based production model one must map the manufacturing operation's critical production-time-path.

Basic Jet Sew Hemmer Critical Production-time-path

A critical production-time-path is made up of the critical operations necessary for maintaining production. For example, if a Hemmer asks for a part and the Loader is unable to comply, the Hemmer will stop. To extend the example further, suppose the Loader was unable to comply because the Clupickers mispicked. If the Hemmer stops, production stops, and production time is lost forever. It is therefore imperative that the Hemmer

be started immediately. To start the Hemmer requires fixing the mispick condition. It is therefore critical that time is spent correcting the mispick condition. The time spent correcting the mispick is part of the critical production-time-path.

Critical production-time-paths show each critical operation, the relationship between the critical operations, and how much time each critical operation fills during a typical work day. To determine the critical production-time-path of a Jet Sew Hemmer, one must first develop a simple model based on a small block of production time. Figure 3-1 is such a model.

Figure 3-1: Critical Production-time-path of a Jet Sew Hemmer - Step 1

Time	Critical Direct Labor Operations	Critical Machine Operations	Critical Indirect Labor Operations	Critical Time Breakdown
t_1			Setup	Servicing
t_2	Load			Servicing
t_3		Pick		**Producing**
t_4		Mispick		Processing
t_5	Fix Mispick			Servicing
t_6		Repick		**Producing**
t_7	Load			Servicing
t_8		Pick		**Producing**
t_9		Mispick		Processing
t_{10}	Fix Mispick			Servicing
t_{11}		Repick		**Producing**
* * * * * * *	* * * etc.	* * * * *	* * * * *	

In Figure 3-1 each block represents a block of time. Obviously the amount of time required to load plies for processing on the Jet Sew Hemmer will be less than the amount of time required to pick the plies. If the relative amounts of time were known, the blocks would be sized accordingly. In this example, the Load block would be much smaller than the Pick block. Since the relative times are not known (yet) this model just serves as a simple start.

There are several points worth noting, however:

1. The blocks of time shown are only the critical blocks. Unfilled blocks can be used to perform other operations. For example, while Direct Labor is loading the Hemmer, the Hemmer must wait, but nothing prevents Indirect Labor (in this case a mechanic) from servicing other machines.
2. Along the same lines, Direct Labor must repair and replace some fabric plies damaged by the Hemmer, but these operations can be performed while the Hemmer is picking and repicking.
3. *The only operations which produce product are the Pick and Repick operations. It is therefore critical that the time spent performing these operations is maximized while the time spent on all the other operations is kept to a minimum.*

Condensed Jet Sew Hemmer Critical Production-time-path

Figure 3-1 tracks time on a small scale. Figure 3-1 can be condensed to track time on a larger scale. Figure 3-2 represents a condensed version of Figure 3-1.

Figure 3-2: Critical Production-time-path of a Jet Sew Hemmer - Step 2

Time	Critical Direct Labor Operations	Critical Machine Operations	Critical Indirect Labor Operations	Critical Time Breakdown
t_1			Setup	Servicing
t_2	Load			Servicing
t_3				
t_4		Pick		**Producing**
t_5				
t_6		Mispick		Processing
t_7				
t_8	Fix Mispicks			Servicing
t_9				
t_{10}		Repick		**Producing**
t_{11}				
* * * * * * * * * * etc. * * * * * * * * * *				

Note that:

1. The time spent by Indirect Labor for setup has not changed.
2. The blocks of time for the other operations have been combined, but the total time spent on each operation has not changed.
3. The total amount of time represented by Figure 3-2 is the same as the total amount of time represented by Figure 3-1. In simpler terms, Figure 3-2 is the same size as Figure 3-1.

Condensed and Refined Jet Sew Hemmer Production Model

Having established a method for condensing each event during a Hemmer's work day, the next step is to generate a completely condensed and refined version of the Hemmer's daily critical time-path. The completely condensed version is shown as Figure 3-3 on the next page.

To give the reader a feel for relative times, each block represents ten (10) minutes. For example, an operation that takes a total of ten (10) minutes per day will span one block. An operation that takes a total of twenty (20) minutes per day will span two blocks.
The reader should note that:

1. The times shown are approximate.
2. The exact times were calculated using the AMCIA Worksheets (described in Appendix Q) and the Time Check Worksheets (presented in the next section).
3. The Hemmer production environment modeled required only one Hemmer setup per day.
4. Other Hemmer production environments are modeled later in this paper (see Appendix M).

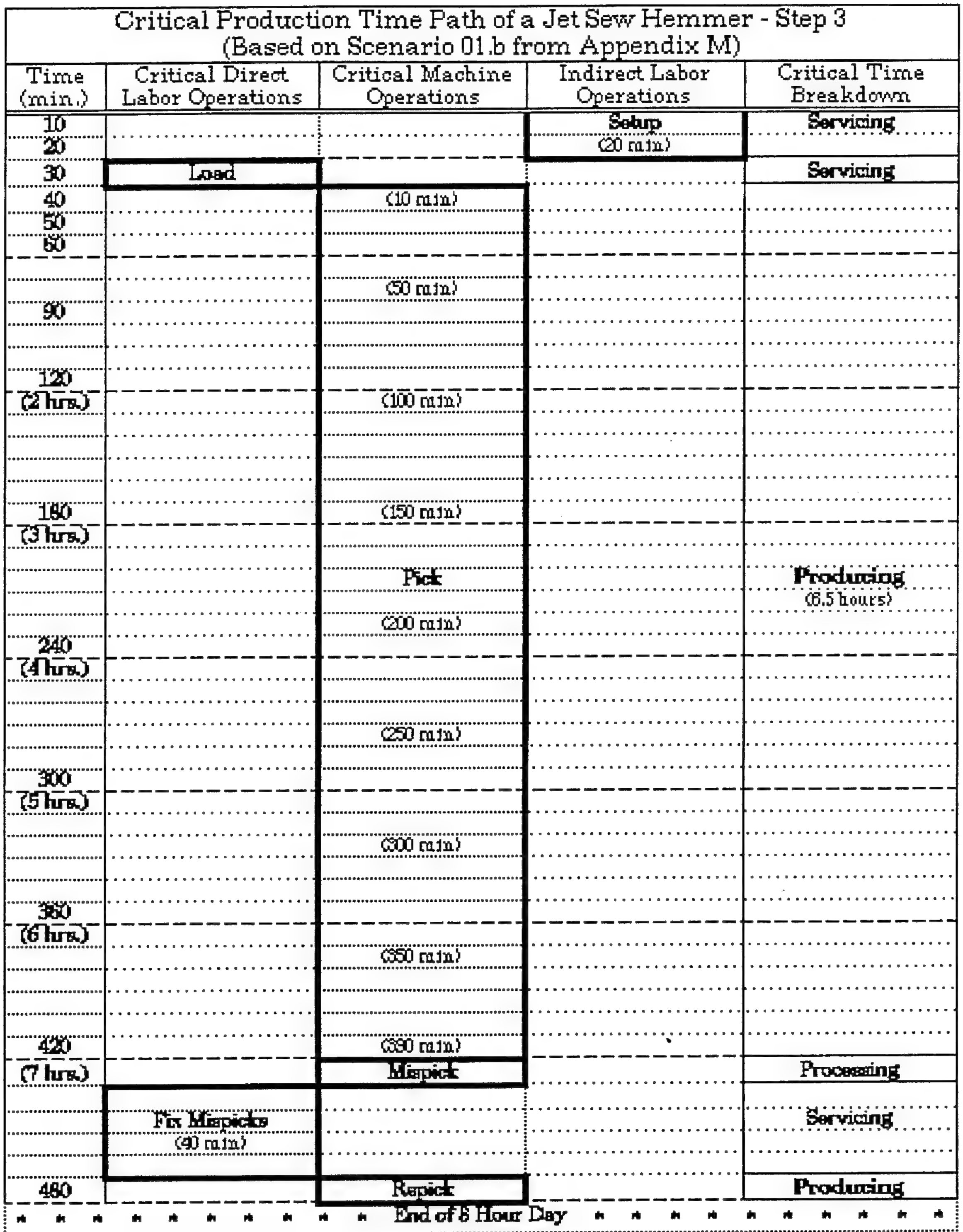

Figure 3-3: Critical Production-time-path of a Jet Sew Hemmer

The refined time-path, shown in Figure 3-3, forms the backbone of a Hemmer production model for one particular production environment, Scenario 01.b as outlined in Appendix M. Other models for different production environments are also based on Appendix M. Such Hemmer production models can be used to calculate the production impact of any change that affects Hemmer performance. The main change of interest in this document is the upgrade from Original Clupickers to Modified Clupickers, but other changes will be considered as well.

Checking the Jet Sew Hemmer Production Model

To ensure that financial calculations based on Figure 3-3 are accurate, a simple check can be carried out. The only time when Figure 3-3 will not be accurate is when the critical production-time-path changes. Under normal circumstances, the only time the critical time-path would change is when the Jet Sew Hemmer produced more errors than direct labor can fix.

For example, supposed the Hemmer produces a lot of defective parts. As long as there is no interference with the critical time-path, good management will instruct direct labor to repair and/or replace these parts. If direct labor's efforts to repair and replaced parts interferes with the Hemmer's performance (i.e. has an impact on the critical time-path) production time is permanently lost. The amount of production time lost does not depend on the Hemmer performance; the production time lost depends on direct labor's performance. In other words, if the Hemmer produces more defective parts that direct labor has time to repair, the critical time-path shifts towards direct labor, and Figure 3-3 becomes inaccurate. So, before conducting extensive financial calculations based on Figure 3-3 it is necessary to check that Figure 3-3 is accurate.

To check that Figure 3-3 is accurate the following equation is used:

$$\text{Time}_{\text{Critical Production}} \geq \text{Time}_{\text{Repair}} + \text{Time}_{\text{Replace}} \qquad (3.1)$$

This equation suggests that the time required to repair and replace defective product must be less than or equal to the Jet Sew Hemmer's critical production time. If Equation 3.1 is not true, then the production bottleneck has shifted from the Jet Sew Hemmer, to the person responsible for conducting the repairs, and Figure 3-3 is invalid as a production model. To solve Equation 3.1 it is necessary to develop an expression for $\text{Time}_{\text{Critical Production}}$.

Using Figure 3-3 it is easy to see that direct labor can be used to conduct repairs only after direct labor has completed loading plies and fixing mispick conditions. (Here mispick conditions refers to machine stoppages

due to mispicks and not production errors due to mispicks.) Also, direct labor can only process plies when the Hemmer is running. Since the Hemmer cannot be running during setup, the block of time allotted for machine setup cannot be used by direct labor to repair and replace mispicked plies. So, one possible expression for $\text{Time}_{\text{Critical Production}}$ is

$$\text{Time}_{\text{Critical Production}} = \text{Time}_{\text{Pick}} + \text{Time}_{\text{Mispick}} + \text{Time}_{\text{Repick}} \tag{3.2}$$

But Equation 3.2 overlooks the fact that if the last ply processed by the Hemmer is damaged beyond repair, an additional 15 minutes will be required to replace and repick the replaced ply (see the Quality Related Costs Worksheet, Equation Q.R.C. 27. Since the entire Hemming process would have to wait for the ply to be replaced, the 15 minute wait would be time taken away from processing. In other words

$$\boldsymbol{\mathit{Time}_{\mathit{Critical\ Production}} = \mathit{Time}_{\mathit{Pick}} + \mathit{Time}_{\mathit{Mispick}} + \mathit{Time}_{\mathit{Repick}} - 15\ \mathit{min.}}$$

(3.3)*

* This equation is presented in ***bold italics*** because it is one of the critical equations involved in the Clupicker Programs listed in Appendix J. The programs are closely linked to Chapter 4 and Appendix I.

From Equation 3. 3 it is possible to infer that the last 15 minutes of a processing run are critical to the Hemmer's performance. If the Hemmer has 15 minutes of plies left to pick (approximately 140 plies), and it proceeds to irreparably damage all of those plies, direct labor will have to spend a great deal of time to replace the damaged plies. That time takes away from the Hemmer's production time and dramatically affects Hemmer efficiency.

While the chances of such serious damage occurring are small, the chances of some damage occurring are very real. Accounting for the affects of damage in the last 15 minutes of a production run makes the critical time-path calculation much more complicated, however. To prevent the cost analysis from become unmanageable, the test team decided to stick with Equation 3.3 by assuming that extra vigilance in the last 15 minutes of production would minimize the production bottlenecks associated with last minute repairs and replacements.

Having decided to keep Equation 3.3 the next step involves calculating $\text{Time}_{\text{Pick}}$, $\text{Time}_{\text{Mispick}}$, and $\text{Time}_{\text{Repick}}$. To calculate values, the following equations can be used:

$$\text{Time}_{\text{Pick}} = \frac{\text{Time}_{\text{Pick}}}{\text{Ply}_{\%}} \text{ x Production}_{\text{Actual}} \qquad (3.4)$$

$$\text{Time}_{\text{Mispick}} = \frac{\text{Time}_{\text{Mispick}}}{\text{Ply}_{(1-\%)}} \text{ x Production}_{\text{Actual}} \qquad (3.5)$$

and

$$\text{Time}_{\text{Repick}} = \frac{\text{Time}_{\text{Repick}}}{\text{Ply}_{(1-\%)}} \text{ x Production}_{\text{Actual}} \qquad (3.6)$$

Using calculations from the Direct Labor Worksheet (located in the Appendix I), Equation 3.4 can be solved using Equations D.L. 11 and D.L. 25. Equation 3.5 can be solved using Equations D.L. 14 and D.L. 25, and Equation 3.4 can be solved using Equations D.L. 19 and D.L. 25.

Solving Equations 3.4 through 3.6 allows Equation 3.3 to be solved. Solving Equation 3.3 is the equivalent of solving the left-hand-side of Equation 3.1. All that remains to completely solve Equation 3.1 are expressions for the components in the right-hand-side of Equation 3.1.

Using calculations described in the Quality Related Costs Worksheet (located in Appendix I), the time spent repairing damaged plies can be expressed as

$$\textbf{\textit{Time}}_{\textbf{\textit{Repair}}} = \frac{\textbf{\textit{\# Repairs}}}{\textbf{\textit{Work Day}}} \; \boldsymbol{x} \; \frac{\textbf{\textit{Time}}}{\textbf{\textit{Repair}}} \qquad \textbf{\textit{(3.7)}}\text{*(see next page)}$$

where the number of repairs per work day equals Equation Q.R.C. 12 and the time per repair equals Equation Q.R.C. 13.

The Quality Related Costs Worksheet can also be used to solve the equation

$$\boldsymbol{Time_{Replace} = \frac{\#\ Scrapped\ Pieces}{Work\ Day} \times \frac{Time}{Replacement}} \qquad \textit{(3.8)*}$$

where the number of scrapped pieces per work day equals Equation Q.R.C. 26 and the time per replacement equals Equation Q.R.C. 27.

* These equations are presented in ***bold italics*** because they are critical equations involved in the Clupicker Programs listed in Appendix J. The programs are closely linked to Chapter 4 and Appendix I.

With expressions for all of the variable listed in Equation 3.1 resolved, it is now possible to solve Equation 3.1. Solving Equation 3.1 using the Worksheet examples yields

$$\text{Time}_{\text{Critical Production}} \geq \text{Time}_{\text{Repair}} + \text{Time}_{\text{Replace}} \qquad (3.1)$$

$$403 \text{ minutes} \geq 68 \text{ minutes} \quad \surd \qquad (3.9)$$

It is left as an exercise for the reader to verify Equation 3.9 using Appendix I and the Clupicker Program information in Appendix J.

Assuming 3.9 is correct, the Hemmer production model, represented by Figure 3-3, is also correct. Knowing that Figure 3-3 is valid, it is now possible to conduct a detailed cost analysis to determine how Clupicker performance affects Jet Sew Hemmer performance and subsequent manufacturing output.

Inter-Office Memorandum

Date:

To:

Reference:

From:

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Chapter 4 - Clupicker Cost Analysis

Background Discussion

The "Final Data Evaluation" section in Chapter 2 shows that the Modified Clupickers performed better than the Original Clupickers. But, just because a machine performs well physically does not mean it performs well financially. For any machine to be successful, it must pay for itself. Determining if a machine will pay for itself is difficult. Determining if a sub-component of a machine will pay for itself is even more difficult. Since Clupickers are parts of Jet Sew Loaders, there are any number of investment scenarios which affect a company's decision to purchase Modified Clupickers.

If, for example, a company has already decided to purchase its first Jet Sew Loader (shirt front, sleeve, pocket, or otherwise) the decision to purchase Modified Clupickers is simple. Since the Modified Clupickers work better than the Original Clupickers without costing any more, why would the company buy the Original Clupickers?[4.1] If, however, a company already has a Jet Sew Loader equipped with Original Clupickers, the company may not be willing to spend the money to replace the Original Clupicker with the Modified Clupickers. If, on the other hand, a company has no Jet Sew Loaders at all, the decision to buy the Modified Clupickers is based on the decision to buy a Loader. If the overall Loader performance in not good enough to justify its expense, the individual Clupicker performances will have no affect on the purchase decision. In other words, if something makes the Loader performance go down more than the Modified Clupicker makes the Loader performance go up, the Modified Clupicker has little impact on the Loader purchase decision.

It should be obvious that in a majority of cases, the decision to purchase Modified Clupickers is closely linked to the decision to purchase Jet Sew Loaders. What is not immediately clear is that the decision to purchase Loaders is affected by the performance of the machines the Loaders are connected to. Since Jet Sew offers a number of Loaders and since these Loaders are connected to a variety of different Jet Sew processing machines, the test team decided to limit the Clupicker cost analysis to just one type of Jet Sew loader (the Jet Sew 5001 Automatic Front Loader) and one piece of Jet Sew processing equipment (the Jet Sew 2261 Centerplaite/Sleeve Hemmer). This decision forms the basis of all of the cost analysis preparation that has taken place up to this point.

Review

By way of a summary, the steps taken in preparation for a Clupicker cost analysis have been:

1. The individual Clupicker performance ratings were determined. This was done in Chapter 2.
2. The device which limits the Clupicker cycling times was identified. In Chapter 3 it was shown that the Clupicker processing speed is limited by the Jet Sew Hemmer.
3. The way Jet Sew Hemmers fit into apparel manufacturing environments was modeled. In Chapter 3 a Jet Sew Hemmer critical production time-path was determined.
4. Time-based information was added to the critical time path. The result was a production model for the Jet Sew Hemmer (Figure 3-3). Remember, that Figure 3-3 only applies to one particular manufacturing scenario, however.
5. The basic validity of the production model was checked. This was done in the last section of Chapter 3.

Remaining Objectives

The remaining portion of this document will be spent:

1. Determining initial assumptions for all subsequent financial analyses.
2. Determining the initial production scenarios to be modeled.
3. Using CAR's AMCIA program to convert the single production model represented by Figure 3-3 into a financial model.
4. Distilling the financial model into a well documented calculation sequence.
5. Using the calculation sequence to evaluate the initial production scenarios selected (and any other production scenarios of interest).
6. Condensing the information from the initial production scenarios into graphs.
7. Looking at the graphs to see if legitimate answers can be found to the questions at the end of Chapter 2 and to see if any additional analyses are required.
8. If necessary, repeating the entire process starting with Step 5 until all of the Chapter 2 questions have been answered.

Initial Assumptions

To ensure that all of the financial models share the same basic starting point, a number of initial assumptions were made.

1. The manufacturing facilities being modeled make dress shirts.
2. The facilities already own at least one Jet Sew 5001 Automatic Front Loader.
3. Each Loader is attached to a Jet Sew 2621 Hemmer.
4. Each Loader has six Clupickers.
5. The facilities are interested in upgrading the Front Loader's Clupickers from the Original Clupickers to the Modified Clupickers.
6. Each Modified Clupicker costs $2000.
7. The facilities use their Clupickers to automatically pick and hem men's, dress-shirt, right fronts only*.
8. A Hemmer running continuously without error, is capable of processing 4,500 right fronts in eight hours.
9. Production ≤ 4,500 shirts/day implies the need for six Clupickers, one Loader, and one Hemmer.
10. The manufacturing facilities are capable of utilizing the full production capacity of Hemmers equipped with Modified Clupickers.
11. A dress shirt takes approximately 15 minutes of direct labor to complete.
12. Dress shirts are sewn with twelve stitches per inch.
13. All plant employees are paid flat hourly wages.
14. Operators and mechanics earn the same amount.
15. A work day had eight hours.
16. A work week had five days.
17. A work year had 49 weeks.

* According to Elroy Pierce, who used to work for Oxford Industries, most shirt manufacturers only use the Jet Sew Hemmers to hem mens', dress-shirt, right fronts. There are a number of reason for this.

1. The margin and demand for quality mens' dress shirts are high enough for medium to large manufacturers to justify the purchase of Jet Sew Hemmers.
2. Traditionally the right fronts of men's shirts are hidden by the centerplaite. (This is probably because most men are right handed and it is easier to fasten the shirt buttons with the right hand). According to Elroy, left fronts can have a maximum variation of 1/4 inch while right fronts, which are hidden, can have variations of up to 1/2 and inch. The error tolerance of the right fronts makes them ideal for use with the Jet Sew Loader because the right fronts can accommodate inaccuracies associated with the loader. (Just for the record, during the Clupicker experiment, the Loader's positioning capabilities proved less than perfect.[4.2])

Initial Production Scenarios

Recognizing that no single production model can apply to every company situation, CAR decided to evaluate a variety of production models. (For a complete list of the production models see Appendix M.) These production models represent a range of production scenarios. The production scenarios are based on the following input variations:

1. The Original versus Modified Clupicker performance ranges initially considered were 99.5% versus 99.9%, 97.51% vs. 98.68%, and 98.76% vs. 99.23%.
2. The facilities modeled used six Clupickers (i.e., had daily production less than or equal to 4,500 units).
3. Hourly wages were \$2.00, \$4.00, \$6.00, \$8.00, and \$10.00 per hour.
4. Style changeovers occurred 1, 3, 6, 9, and 12 times per day.

All of the above assumptions and ranges were used to provide input data in Dr. Steve Davis's Apparel Manufacturing Capital Investment Advisor (AMCIA) program version 3.1 written for Microsoft Excel version 4.0 and higher.

Using AMCIA to Convert the Production Model into a Financial Model

The Apparel Manufacturing Capital Investment Advisor (AMCIA) is a microcomputer program designed to help apparel manufacturers make technology purchase decisions. AMCIA helps managers make informed purchase decisions by helping managers consider all the cash flows associated with the new technology. AMCIA helps managers consider all cash flows by breaking up investment components into a series of

worksheets. These worksheets are listed below in the order they are displayed by the AMCIA program.

1. Directions
2. Company Data Sheet
3. Investment, Installation, and Depreciation
4. Old Equipment Sale
5. Direct Labor
6. Indirect Labor
7. Materials
8. Maintenance
9. Quality Related Costs
10. Inventory
11. Fabric Utilization
12. Miscellaneous
13. Quality Revenues
14. Response-time Revenues

Each of the AMCIA worksheets is discussed in detail in Appendix I. The AMCIA analysis, presented in the worksheets, is related to the Hemmer production model, produced in Chapter 3, and uses all of the basic assumptions listed above. In addition, the example AMCIA analysis assumes that Production Scenario 01.b from Appendix M applies. In other words, the plant being modeled has approximately 100 employees earning $4.00 per hour, uses six Clupickers, and changes styles one time a day every working day of the year.

Distilling the Financial Model into a Calculation Sequence

The AMCIA worksheets in Appendix I show how complex it is to determine AMCIA input values. Appendix M shows how many different input combinations needed evaluating. To ensure that all of the calculations were documented and tracked, CAR developed a step-by-step procedure for converting production scenario input values into well documented AMCIA output values. The procedure was as follows:

1. All of the equations necessary for determining AMCIA input values were identified (see Appendix I).

2. The equations were incorporated into a program in order to minimize human keystroke related errors (see Appendix J). The program was called the Clupicker Program and should not be confused with the AMCIA program.
3. A large selection of production scenarios were outlined (see Appendix M). The production scenarios provided the Clupicker Program input values, and the Clupicker Program, in turn, provided the AMCIA program input values.
4. One by one each production scenario, with its own unique set of input values, was selected (see Appendix K for an example).
5. The production scenario input values were entered into the Clupicker Program which generated the necessary AMCIA input values.
6. In AMCIA the first part of the Direct Labor Worksheet was completed (again, refer to Appendix K for an example). The Direct Labor Worksheet could not be completed until the AMCIA Company Data Sheet was completed, however (see Step 9 below).
7. Next, the Quality Related Cost Worksheet was completed. Again, the Clupicker Program provided the necessary AMCIA input values.
8. Chapter 3's equations were used to check that the amount of time available for production (Equation 3.3) was greater than the amount of time required for repairs and replacements (Equation 3.7 + Equation 3.8). Specifically, refer to the Clupicker Program's storage registers 42 and 43.
9. The Company Data Sheet was completed.
10. The Direct Labor Worksheet was now completed.
11. The Investment, Installation, and Depreciation Worksheet was completed.
12. The Indirect Labor Worksheet was completed.
13. The outputs of each AMCIA worksheet were recorded (again, see Appendix K).
14. All of the pertinent AMCIA outputs were collected and used to calculate the net present value of the selected scenario (see Appendix L for example).
15. The net present values were entered into Appendix M next to their associated production scenarios.

Note: The above procedure linked the production scenarios to the Clupicker Program, the AMCIA program, and the final net

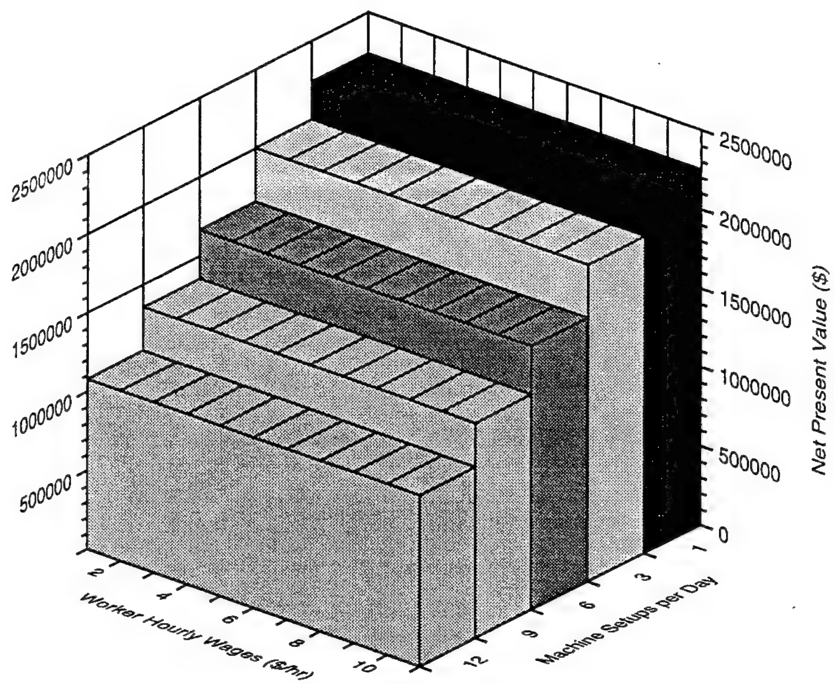
present value calculations. The entire process is lengthy and complicated and the reader is *strongly* encouraged to read the "Calculation Sequence" presented at the start of Appendix J.

Using the Calculation Sequence to Evaluate the Initial Production Scenarios

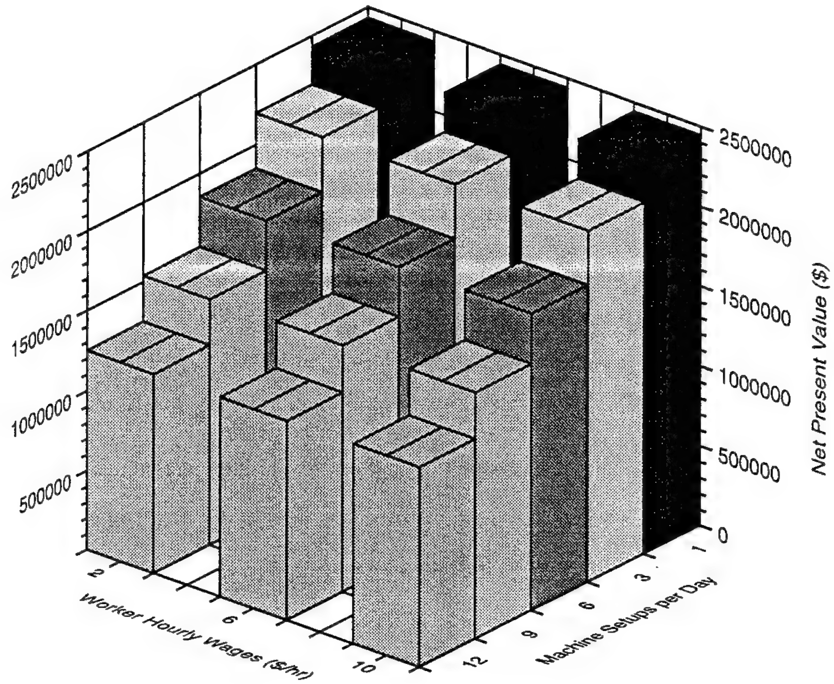
Having developed a well defined and repeatable calculation sequence, each production scenario was evaluated (see Appendix M).

Condensing the Production Scenario Information Into Graphs

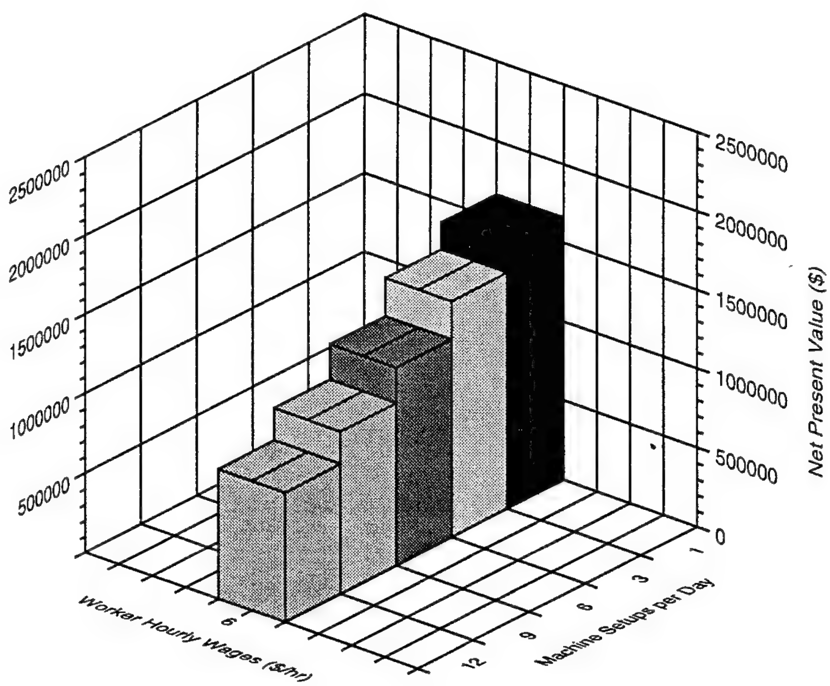
The graphs shown below were derived from the data listed in Appendix M.



Graph 4-1: Scenario 01
(99.50% versus 99.90%)



Graph 4-2: Scenario 02
(97.51% versus 98.68%)



Graph 4-3: Scenario 03
(98.76% versus 99.23%)

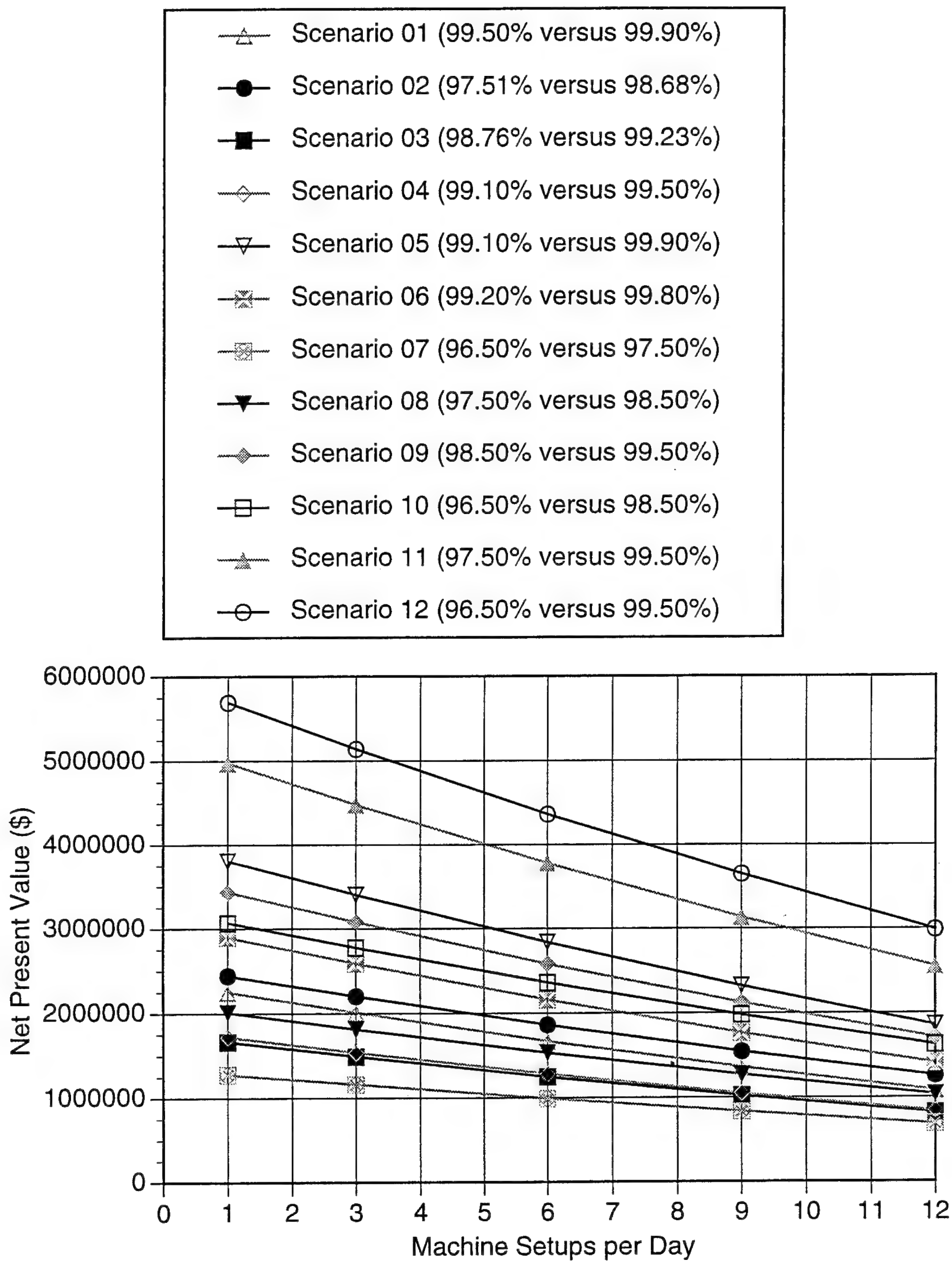
General Observations Based on Graphs 4-1 through 4-3

- Graph 4-1 shows that changes in hourly worker wages have little affect on the net present values associated with the purchase of six Modified Clupickers.
- Graph 4-2 also supports this observation.
- The worst case scenario, Scenario 03, is based on experimental data presented in Chapter 2. Scenario 03 clearly demonstrates that if manufacturing plants can make their production match the Hemmer output, the decision to purchase six Modified Clupickers is worth a minimum of $80,000, provided the number of daily setups does not exceed twelve.
- Using just the data from Scenarios 01, 02, and 03, it is not possible to predict the net present values of other Clupicker performance scenarios.

The process of determining the net present values shown in Graph 4-1 through 4-2 was lengthy, and frankly no business would be willing to expend the time and effort to perform such a detailed analysis. Unfortunately, the data did not provide a means for quickly predicting net present values for other Clupicker performances scenarios.

Additional Scenarios Evaluated in Order to Establish Trends

To provide businesses with a tool for quickly making conservative estimates of the net present values associated with other Clupicker performance scenarios, CAR conducted additional scenario calculations (see Appendix N). The additional scenarios (Scenarios 04 through 12) were used to construct "Clupicker Performance Models" which provide simple methods for calculating the net present value of a Clupicker and/or Hemmer purchases, avoiding the lengthy process associated with a complete AMCIA analysis. (For more information on the models see Equations 4.19 and 4.20.)



Graph 4-4: Scenarios 01 through 12

Graph 4-4 clearly shows that the data exhibits linear tendencies and seems to converge towards some point beyond the limits set in the graph. Linear regression analyses (see Appendix N) of the points shown in Graph 4-4 produced the following equations (in the form y = mx + b) and the associated correlation coefficients (- 100% being perfect negative linear correlation):

$$f(x)_{\text{Scenario 01}} = (-1.0624593 \times 10^{5}) \times X + (2.3320450 \times 10^{6}) \quad (4.1)$$

$$R_{\text{Scenario 01}} = -0.9987966 \approx -99.88\% \text{ negative correlation}$$

$$f(x)_{\text{Scenario 01}} = (-1.0621654 \times 10^{5}) \times X + (2.3318272 \times 10^{6}) \quad (4.1)^{R}$$

$$R_{\text{Scenario 01}} = -0.9988082 \approx -99.88\% \text{ negative correlation}$$

$$f(x)_{\text{Scenario 02}} = (-1.0780707 \times 10^{5}) \times X + (2.5293970 \times 10^{6}) \quad (4.2)^{R}$$

$$R_{\text{Scenario 02}} = -0.99911724 \approx -99.91\% \text{ negative correlation}$$

$$f(x)_{\text{Scenario 03}} = (-7.6628594 \times 10^{4}) \times X + (1.7238135 \times 10^{6}) \quad (4.3)^{R}$$

$$R_{\text{Scenario 03}} = -0.9989276 \approx -99.89\% \text{ negative correlation}$$

$$f(x)_{\text{Scenario 04}} = (-8.0116119 \times 10^{4}) \times X + (1.7813951 \times 10^{6}) \quad (4.4)$$

$$R_{\text{Scenario 04}} = -0.9988683 \approx -99.89\% \text{ negative correlation}$$

$$f(x)_{\text{Scenario 05}} = (-1.7749724 \times 10^{5}) \times X + (3.9435991 \times 10^{6}) \quad (4.5)$$

$$R_{\text{Scenario 05}} = -0.9988499 \approx -99.88\% \text{ negative correlation}$$

$$f(x)_{\text{Scenario 06}} = (-1.3539927 \times 10^{5}) \times X + (3.0009091 \times 10^{6}) \quad (4.6)$$

$$R_{\text{Scenario 06}} = -0.99884149 \approx -99.88\% \text{ negative correlation}$$

$$f(x)_{\text{Scenario 07}} = (-1.3539927 \times 10^{5}) \times X + (3.0009091 \times 10^{6}) \quad (4.7)$$

$$R_{\text{Scenario 07}} = -0.99884149 \approx -99.88\% \text{ negative correlation}$$

R As mentioned in Appendix M and again in Appendix O, the data generated in Scenarios 01, 02, and 03 were reevaluated in Appendix N (the superscript R implies revised). The revised values were used to produce Graph 4-4 and Graphs 4-5 and 4-6 on the following pages.

$$f(x)_{\text{Scenario 08}} = (-1.3539927 \times 10^5) \times X + (3.0009091 \times 10^6) \tag{4.8}$$
$$R_{\text{Scenario 08}} = -0.99884149 \approx -99.88\% \text{ negative correlation}$$

$$f(x)_{\text{Scenario 09}} = (-1.3539927 \times 10^5) \times X + (3.0009091 \times 10^6) \tag{4.9}$$
$$R_{\text{Scenario 09}} = -0.99884149 \approx -99.88\% \text{ negative correlation}$$

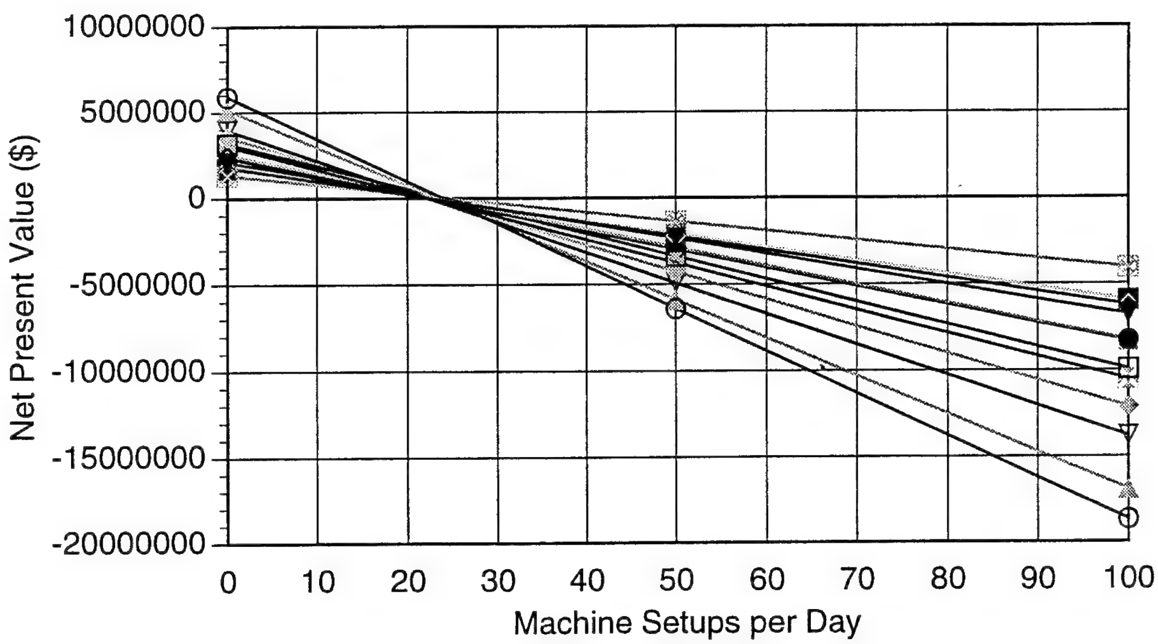
$$f(x)_{\text{Scenario 10}} = (-1.3539927 \times 10^5) \times X + (3.0009091 \times 10^6) \tag{4.10}$$
$$R_{\text{Scenario 10}} = -0.99884149 \approx -99.88\% \text{ negative correlation}$$

$$f(x)_{\text{Scenario 11}} = (-1.3539927 \times 10^5) \times X + (3.0009091 \times 10^6) \tag{4.11}$$
$$R_{\text{Scenario 11}} = -0.99884149 \approx -99.88\% \text{ negative correlation}$$

$$f(x)_{\text{Scenario 12}} = (-1.3539927 \times 10^5) \times X + (3.0009091 \times 10^6) \tag{4.12}$$
$$R_{\text{Scenario 12}} = -0.99884149 \approx -99.88\% \text{ negative correlation}$$

Using these equations for lines, it was possible to extend the lines shown in Graph 4-4 to see if the lines intersected at a common point. The resulting graph (Graph 4-5, below) gives a visual idea of the how the lines extended.

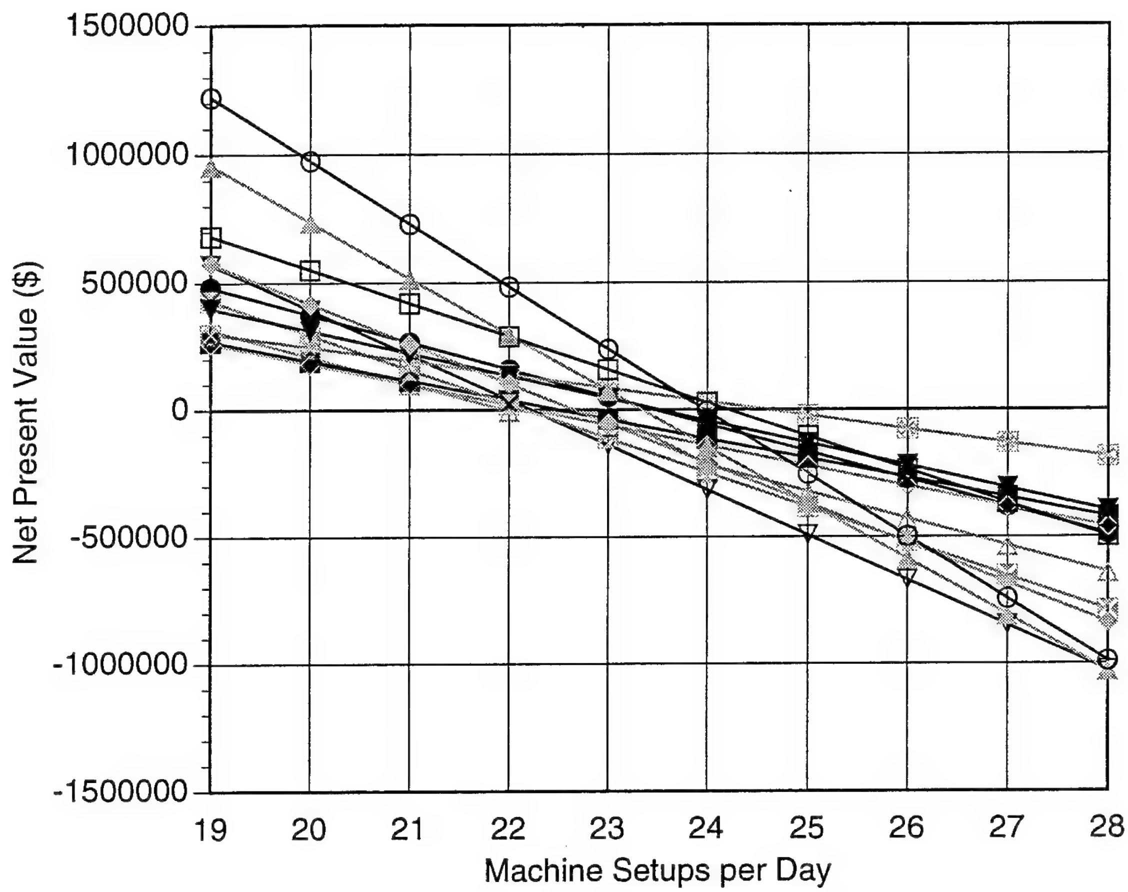
Note: The legend shown in Graph 4-4 also applies to Graph 4-5.



Graph 4-5: Scenarios 01 through 12, Big-picture view

Graph 4-5 shows that around 23 setups, most of the scenario lines appear to intersect. A closer look at this area yielded the following graph.

Note: The legend shown in Graph 4-4 also applies to Graph 4-6, below.



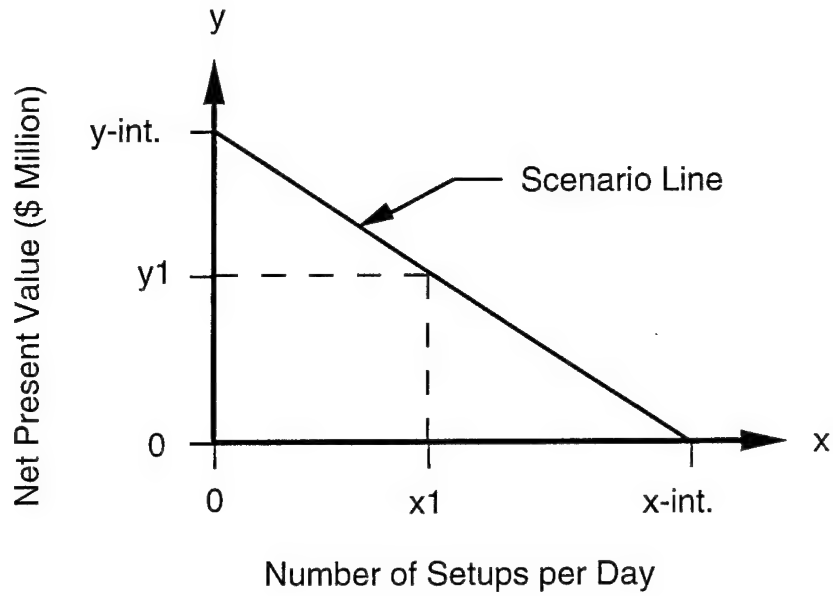
Graph 4-6: Scenarios 01 through 12, Close-up view

Graph 4-6 shows that although the lines do not all intersect at one point, they do all cross the x-axis between 22 and 25 machine setups per day. So, what does all this mean?

The fact that the various production scenarios exhibit a linear relationship between Setups per Day and Net Present Value (Graphs 4-4 and 4-5), and the fact that the scenarios group about 22 to 25 Machine Setups per Day (Graphs 4-5 and 4-6) imply that it should be possible to construct a conservative and simple (first order) model relating Clupicker performances to net present values.

Development of a First Order Model Relating Clupicker Performances to Net Present Values.

Graph 4-7 below serves as the starting point for the development of a Clupicker performance model.



Graph 4-7: Basis for Clupicker Performance Model

Graph 4-7 shows a Scenario Line. The Scenario Line plots the relationship between Setups per Day and Net Present Value for a particular Clupicker production scenario. (Specific examples of Scenario Lines can be seen in Graphs 4-4 through 4-7.) Finding the x- and y-intercepts associated with a particular Clupicker production scenario allows the Scenario Line to be plotted. With the Scenario Line plotted, the Net Present Value (y1) associated with a specific number of setups (x1) can be determined using the following mathematical relationship (based on Graph 4-7):

$$y_1 = -\frac{y_{int.}}{x_{int.}} \times (x_1) + y_{int.} \qquad (4.13)$$

Equation 4.13 is in the form

$$y = mx + b \quad \text{(the equation for a line)}$$

where

$$y = y_1 \ , \ m = -\frac{y_{int.}}{x_{int}} \ , \ x = x_1 \ , \text{ and } b = y_{int.}$$

Solving Equation 4.13 requires relating Original and Modified Clupicker performances to $y_{int.}$ and $x_{int.}$. Relating Clupicker performances to the y-intercept ($y_{int.}$) was partially done in Equations 4.1^R through 4.12 As mentioned earlier, Equations 4.1^R through 4.12 are the results of linear regression analyses (see Appendix N. This means that Equations 4.1^R through 4.12 can be used to construct the y-intercept table shown in Appendix O. A similar table can be constructed for the x-intercept values (again, see Appendix O).

In Appendix O the key to developing a complete Clupicker Performance Model lies in determining the mathematical relationships between the Original and Modified Clupicker performances and the x- and y-intercepts. This is done using a statistical process called Multiple Regression Analysis. Multiple Regression Analysis allows multiple input values to be related to one or more output values. The relationship can be simple (first order, i.e., linear), or complex (second order and higher).

As discussed earlier, the Clupicker Performance Model must be simple and fairly accurate if industry is going to use the model. Therefore, the regression analysis must produce a first order model (linear) with two independent variables (Original Clupicker Performance and Modified Clupicker Performance). The results of the x- and y-intercept multiple regression analyses are discussed in Appendix O. For the sake of continued discussion, Appendix O produces the following equations:

$$y_{int.} = (-1.5065226 \times CP_{Original}) + (2.5947051 \times CP_{Modified}) - 106.6092405 \qquad (O.1)$$

$$= (-1.5065226) \times [CP_{Original} - (1.7223141 \times CP_{Modified}) + 70.7651120] \qquad (4.14)$$

$R^2 = 0.9232612$ (implying fair linearity)

and

$$x_{int.} = (-0.6522635 \times CP_{Original}) - (0.2517017 \times CP_{Modified}) + 111.9543082 \qquad (O.2)$$

$$= (-0.6522635) \times [CP_{Original} + (0.3858896 \times CP_{Modified}) - 171.6396950] \qquad (4.15)$$

$R^2 = 0.996927$ (implying good linearity)

In both Equation O.1 and Equation O.2

$$CP \equiv \text{Clupicker Performance} \tag{4.16}$$

Now we finally have all the components needed to produce a mathematical equation which relates Original and Modified Clupicker Performances to Net Present value. Equation 4.13 states:

$$y_1 = -\frac{y_{int.}}{x_{int.}} \times (x_1) + y_{int.} \tag{4.13}$$

Rearranging yields

$$y_1 = y_{int.} \left(-\frac{x_1}{x_{int.}} + 1 \right) \tag{4.17}$$

To test the performance of Equation 4.17 versus AMCIA, Table 4-1 was constructed (see next page). The x- and y-intercept values come from Appendix O's Fit Data. The NPV_{Actual} values come from Appendix N.

Table 4-1: Net Present Value Calculations (Equation 4.17 versus AMCIA Calculations) All Calculations Assume 6 Setups Per Day					
Scenario	y-intercept	x-intercept	$NPV_{Calc.}$ ($\$ \times 10^6$)	NPV_{Actual} ($\$ \times 10^6$)	Δ% Error
01	2.7028000	21.9090867	1.962614	1.668473	+17.6293533
02	2.5352398	23.5141672	1.888335	1.859867	+1.5306471
03	2.0791743	22.5604018	1.526212	1.246216	+22.4676942
04	2.2675270	22.2706728	1.656627	1.281550	+29.2674496
05	3.3054091	22.1699921	2.410846	2.835861	-14.9871591
06	2.8952863	22.1299359	2.110299	2.155804	-2.1108134
07	0.9950756	24.4699614	0.751085	0.991717	-24.2641802
08	2.0832581	23.5659961	1.552852	1.530446	+1.4640177
09	3.1714406	22.6620309	2.385726	2.578860	-7.4891231
10	3.5897807	24.2182597	2.700424	2.361525	+14.3508538
11	4.6779632	23.3142944	3.474076	3.777341	-8.0285312
12	6.1844858	23.9665580	4.636207	4.362498	+6.2741347
			Mean Error		+3.0087157
			Std. Dev. Error		15.8163438

Clearly, Equation 4.17 is not perfect, but reducing Equation 4.17's output by 20% (3% + 16% + additional 1%) yields a conservative first approximate of the Net Present Value associated with replacing Original Clupickers performing at one level, with Modified Clupickers performing at another level, assuming a specified number of setups per day. In other words:

$$y_1 = 80\% \times y_{int.} \left(-\frac{x_1}{x_{int.}} + 1 \right) \qquad (4.18)$$

Final Clupicker Performance Models

Substituting Equation 4.14 and 4.15 for $y_{int.}$ and $x_{int.}$, respectively, and rearranging yields

$$y_1 = \{-1.8477472 \times [CP_{Original} - (1.7223141 \times CP_{Modified}) + 70.7651120]\}$$
$$\times \left\{ \left[\frac{x_1}{[CP_{Original} + (0.3858896 \times CP_{Modified}) - 171.6396950]} \right] + 0.6522635 \right\}$$

Equation 4.19: NPV of Clupicker Replacement

where

y_1 = The net present value (in millions of dollars) associated with replacing Original Clupickers with Modified Clupickers.
Example: $y_1 = 0.991717$ implies an NPV of $991,717.

$CP_{Original}$ = Clupicker $\text{Performance}_{Original}$ in percent.
Example: Enter 96.5 for 96.5%. **Do not** enter 0.965 for 96.5%.

$CP_{Modified}$ = Clupicker $\text{Performance}_{Modified}$ in percent.
Example: Enter 97.5 for 97.5%. **Do not** enter 0.975 for 97.5%.

x_1 = Number of Setups per Day
Example: Any whole number from 1 to 12. Numbers larger than 12 should not be entered (see discussion of Appendices Q and R, below).

Remember, Equation 4.19 should be used by companies who are considering replacing their Original Clupickers with Modified Clupickers.

Subtracting the cost of a Jet Sew Hemmer from Equation 4.19 yields

$$y_2 = y_1 - \text{Cost}_{Hemmer}$$

Equation 4.20: NPV of Jet Sew Hemmer Purchase

where

y_2 = The net present value (in millions of dollars) associated with purchasing a Jet Sew Hemmer equipped with Modified Clupickers. Example: y_2 = 0.751085 implies an NPV of $751,085

y_1 = The net present value (in millions of dollars) associated with replacing Original Clupickers with Modified Clupickers from Equation 4.19 (**see note below**).
Example: y_1 = 0.99717 implies an NPV of $991,717

$Cost_{Hemmer}$ = The Cost of a Jet Sew Hemmer expressed in millions of dollars.
Examples: If a Hemmer costs $75,255 enter 0.0752555.
If a Hemmer costs $752,550 enter 0.7525550.
If a Hemmer costs $7,525,500 enter 7.5255500.

Note: Instead of using $CP_{Original}$ = Clupicker $Performance_{Original}$
use $CP_{Original}$ = Direct Labor Efficiency

For an explanation of how to calculate Direct Labor Efficiency, see Appendix I page 18.

Equation 4.20 should be used by companies who are considering purchasing a Jet Sew Hemmer equipped with Modified Clupickers.

It is left as an exercise for a mathematician to determine better fitting and simpler mathematical expressions that approximate the AMCIA output values calculated in Appendix N.

Final Clupicker Questions Answered

Now that the AMCIA financial data has been collected, analyzed, and simplified, the unanswered questions at the end of Chapter 2 can be addressed. The Chapter 2 questions were:

1. Are the performance improvements shown in Chapter 2 sufficient to justify replacing Original Clupickers with Modified Clupickers?

2. Are the Clupicker performances, from Chapter 2, sufficient to justify investing in Clupicker technology at all?

3. What other factors influence the decision to replace the Original Clupickers with the Modified Clupickers?

4. Are there other factors which have a greater influence on Clupicker performance than the features incorporated into the Modified Clupicker?

5. Are there other improvements which could make the Loader/Clupicker technology better, i.e. more financially attractive?

With the Appendix M through O data in hand, it is now possible to answer question one through four. Question five will be addressed in the section discussing Appendix P and Appendix Q.

Question 1
Are the performance improvements shown in Chapter 2 sufficient to justify replacing Original Clupickers with Modified Clupickers?

Answer 1
Graphs 4-1 through 4-3 show that regardless of the production scenario, the decision replace the Original Clupickers with the Modified Clupickers can translate into a net present value of at least $429,966 even with 12 machine setups per day. So the answer to Question 1 is definitively, "Yes."

As the examples in Appendices J and K show, most of this net present value results from increased annual production capacity obtained by using the Modified Clupickers. The net present values in Appendix assume that the company interested in purchasing the Modified Clupickers will be able to take advantage of the added production capacity. In other words, the AMCIA analysis assumes that the Loader with its Clupickers is the production bottleneck.

Assuming the Loader and its Clupickers are the production bottleneck, the AMCIA analysis overwhelmingly supports the decision to purchase the Modified Clupickers, even when the Clupicker performance values are as low as 98.68%. Chapter 2 showed that even the Original Clupickers can perform at or above 98.68%.

In the face of such overwhelming evidence supporting the decision to purchase Clupickers the question is raised: "Why are companies that have Clupickers not able to realize a return on investment, and why are companies that don't have Clupicker systems not buying them?". These

question and others will be addressed in the section discussing Appendix Q and Appendix R.

Question 2

Are the Clupicker performances, from Chapter 2, sufficient to justify investing in Clupicker technology at all?

Answer 2

Question 1 focused on replacement purchases of Clupickers. Question 2 focuses on initial Clupicker purchases. Like Question 1, however, Question 2 can be answered: "Yes."

The lowest net present value obtained in the AMCIA analyses of Appendix M was $429,966. This value was based on an after tax investment of $8,781 (six Modified Clupickers). The $429,966 net present value was mostly derived from added production capacity. With the combined cost of a Jet Sew Hemmer and Loader less than $100,000, the associated net present value should be in the neighborhood of $300,000. The labor and machine savings associated with a complete Hemmer/Loader purchase would add even more to the $300,000 present value making the decision to purchase a Hemmer and Loader a forgone conclusion.

Again the question arises, "If the cost analysis is so heavily in favor of purchasing complete Jet Sew Hemmers and Loaders, why aren't more companies purchasing the units?" And again, this question and other related questions will be addressed in the section discussing Appendix Q and Appendix R.

Question 3

What other factors influence the decision to replace the Original Clupickers with the Modified Clupickers?

Answer 3

CAR's AMCIA cost analysis focused on five of the fourteen AMCIA worksheets. (The reasons for this are given in Appendix I). The five worksheets CAR analyzed were:

1. Company Data Sheet
2. Investment, Installation, and Depreciation Worksheet
3. Direct Labor Worksheet
4. Indirect Labor Worksheet
5. Quality Related Costs Worksheet

Of these five worksheets only the last three contributed to a positive net present value for the complete analysis. Of these three worksheets Direct Labor contributed the most while Indirect Labor contributed the least (see example in Appendix L).

In fact, the Direct Labor worksheet contributed so much to the net present values in each of the Clupicker cost analyses that CAR recommends future analyses focus only on the Direct Labor worksheet. **It is important to note, however, that the Direct Labor Worksheets positive net present values were not related to labor savings, but rather increased production capacity.** This is a significant point.

Companies looking to justify Clupicker purchases based on labor savings alone may be disappointed. A company that has a direct labor efficiency of 85% (this is admittedly high) may think that adding Clupickers with an efficiency rating of 99.5% will increase their overall direct labor efficiency. However, the discussion at the end of Appendix I's Direct Labor Worksheet shows that a Clupicker performance of 99.5% translates to a direct labor efficiency of only 84.6% (84.5589% was the calculated value).

Also, the assumption that a Hemmer/Loader can completely automate the production of shirt right front hems is a false assumption. As explained in Appendix I's Direct Labor Worksheet, and supported by Appendix Q's Time Check calculations, significant amounts of time (anywhere from 44 to 229 minutes) are required to correct errors caused by the Clupickers. Since the Clupicker errors occur at random (i.e., not all at once), and since the analysis assumes the hemming operation is a production bottleneck, someone must watch over the Clupicker at all times.

The real advantage of purchasing a Clupicker system is that, even with liberal allowances for proper adjustment, the Clupickers can extend a company's production capacity (see the Direct Labor Worksheet's "Implied change in annual production capacity" heading in Appendix I). But increased production capacity is not the only factor that should influence the decision to purchase Clupicker technology.

The next most significant benefit to purchasing Clupicker technology is in the area of Quality Related Costs. As the example in Appendix K shows, increasing the picking efficiency from 99.50% to 99.90% can reduce the labor cost of repair and the net cost of seconds to the tune of $3,412 over the depreciation life of the Clupickers. While this may not seem significant, it is enough to justify the cost of at least two Clupickers (after taxes).

Finally, substantial benefits may be derived from reductions in Indirect Labor input (mechanics, etc.). Although the Indirect Labor Worksheet (described in Appendix I) assumed that virtually no changes would occur

in the number of Loader/Clupicker setups required per day, in actuality, it is quite possible that the Modified Clupickers would substantially reduce the number of setups required per year.

As discussed in Chapter 2, CAR spent a great deal of time adjusting the Original Clupickers so that they worked well. Virtually no time was spent adjusting the Modified Clupickers. In a production environment it is highly unlikely that indirect labor will be given the luxury of 15 minutes per setup as assumed in the AMCIA analysis. Since the Modified Clupickers required virtually no setup, it is reasonable to assume that in a production environment the Modified Clupickers could lead to substantial Indirect Labor cost savings.

Question 4
Are there other factors which have a greater influence on Clupicker performance than the features incorporated into the Modified Clupicker?

Answer 4
From the mathematical models developed in this chapter there are six key factors which affect Clupicker performance. (Remember, "performance" implies financial performance.) They are, listed in order of importance:

1. **The company's ability to capitalize on increased production capacity.**
2. **Bundle quality.**
3. Modified Clupicker performance.
4. Original Clupicker performance.
5. Setups per day.
6. Hourly wages.

Explanations follow:

As mentioned in the answer to Question 3, the ability to increase production capacity is the single largest benefit to purchasing Clupicker technology. If the Clupickers are not the production bottleneck (i.e., if buying Clupickers will not increase production capacity), there is no point in purchasing them.

Bundle quality also has a dramatic affect on Clupicker performance. This project did not attempt to quantify the impact of bundle quality on Clupicker performance, but the project was initially hampered by bundle quality. As discussed in Chapter 2, the test team had to develop a machine (the Bologna

Slicer) to guarantee bundle quality so that Clupickers could be adjusted, calibrated, and experimented on.

A high quality bundle of cut fabric pieces is characterized by the following:

1. Well aligned edges
2. Vertical stacked appearance
3. Non-fused edges
4. Non-fraying edges
5. Minimum ply-to-ply surface fiber entanglement
6. No splitter paper

The well aligned edges and vertical stacked appearance ensure that as Clupickers process the bundle the plies in the bundle do not change position relative to the Clupickers and the Hold-down Fingers. This is important because the Loaders have no way of automatically adjusting the Clupicker and Hold-down Finger positions.

Non-fused edges, non-fraying edges, and minimum ply-to-ply surface fiber entanglement all relate to ply separation. If any of these conditions is not met the bundle fabric pieces will tend to stick together. If the fabric pieces want to stick together, the Clupickers may accidentally pick up two or more pieces at once.

Introducing splitter (tissue) paper between the fabric pieces would minimize the tendency to stick together, but splitter paper interferes with Clupicker performance. Loaders have no way of knowing if fabric is being processed or splitter paper. If the Clupickers pick up splitter paper the paper will be processed just like fabric. This wastes time an resources. If the Clupickers cannot pick up the splitter paper, the Loader and Hemmer stop and production is lost.

To minimize Clupicker related production errors and delays, a company must first maximize its bundle quality. This can be done several ways. To ensure that a bundle has well aligned edges and a vertical stacked appearance:

1. Use automated cutting equipment to produce cut parts for Clupicker operations. Automated cutters produce more consistent parts than manual cutters.
2. Use a stiffer spreading paper under the Clupicker bundles. The stiffer paper helps reduce bundle distortion during handling.
3. Lift the bundles with two hands to avoid shifting the plies.

4. Lift the bundles on the edges perpendicular to the edge the Clupicker will pick. This ensures that if the plies shift they shift from side-to-side with respect to the Clupickers instead of in and out.
5. If possible keep the Clupicker bundles small. Several small bundles are easier to handle and load than one large bundle.

To ensure that bundle pieces do not stick to each other:

1. Avoid getting the cutting blade hot. This prevents fusing and minimizes edge fraying. Lower blade temperatures can be achieved by regular sharpening, reduced fabric compression (i.e., weaker vacuum hold-down), forced cooling, blade lubrication, reduced cutting height, and lower cutting speeds.
2. Reduce edge fraying using the cutting blade techniques discussed above and by minimizing contact with the bundle edges.
3. Reduce ply-to-ply attraction by minimizing ply-to-ply shifting and reducing fabric compression. Ply-to-ply shifting promotes surface fiber entanglement and electrostatic attraction. Ply-to-ply shifting occurs mostly during spreading when the plies are not being spread tension-free. Fabric compression occurs when the lower plies are weighed down by the upper plies (i.e., in thick spreads). Compression also occurs on the vacuum bed of automated cutters.

If fabrics have to be separated to avoid shading or because they belong to different lots, decide whether splitter paper has to be used.

1. If splitter paper has to be used decide if it is better for the Clupickers to process the paper or to mispick, and choose your paper accordingly. Thin flexible paper will pick better than thick stiff paper.
2. Splitter paper can be avoided by reducing the bundle sizes. Remember, production is only as fast as the slowest operation. If the hemming operation is indeed the slowest operation in the plant, reducing the speed of the spreading and cutting operation (by reducing bundle sizes) will have no impact on production throughput.

This ends the discussion of the two factors which have a greater influence on Clupicker performance than the features incorporated into the Modified Clupicker. Several other factors influence Clupicker performance, however.

To determine which of the remaining factors influenced Clupicker performance and to what extent, Appendix P was constructed. Appendix P uses the extreme values of $CP_{Original}$ (CPO, Clupicker Performance Original), $CP_{Modified}$ (CPM, Clupicker Performance Modified), and x_1 (SET, Setups per Day) taken from Appendix N. These extreme values are plugged into Equation 4.19 to see what affect extreme input changes have on Equation 4.19's output y_1 (NPV, Net Present Value).

Appendix P clearly shows the Equation 4.19 is most dramatically affected by the Modified Clupicker performance. The Original Clupicker performance has the next greatest impact, and the number of setups per day has a smaller, but significant, impact on Equation 4.19. Since Equation 4.20 is closely related to Equation 4.19 the same holds true. The Modified Clupicker performance has the greatest affect on the net present value of a Hemmer purchase. The Original Clupicker performance has the next greatest affect, and the number of setups per day has a smaller affect. As for worker hourly wages, Graphs 4-1 through 4-3 show that changes in hourly labor costs have little impact on the Clupicker cost performance.

In summary, the answer to Question 4 is, "Yes, there are two factors which have a greater influence on Clupicker performance than the features incorporated into the Modified Clupicker. First, a company's ability to capitalize on the increased production capacity of existing Clupicker technology is more important than the benefits derived from the Modified Clupickers. Second, poor bundle quality can reduce a Clupicker's performance more than fabric changes within the bundle."

Question 5

Are there other improvements which could make the Loader/Clupicker technology better, i.e. more financially attractive?

This question requires some background discussion.

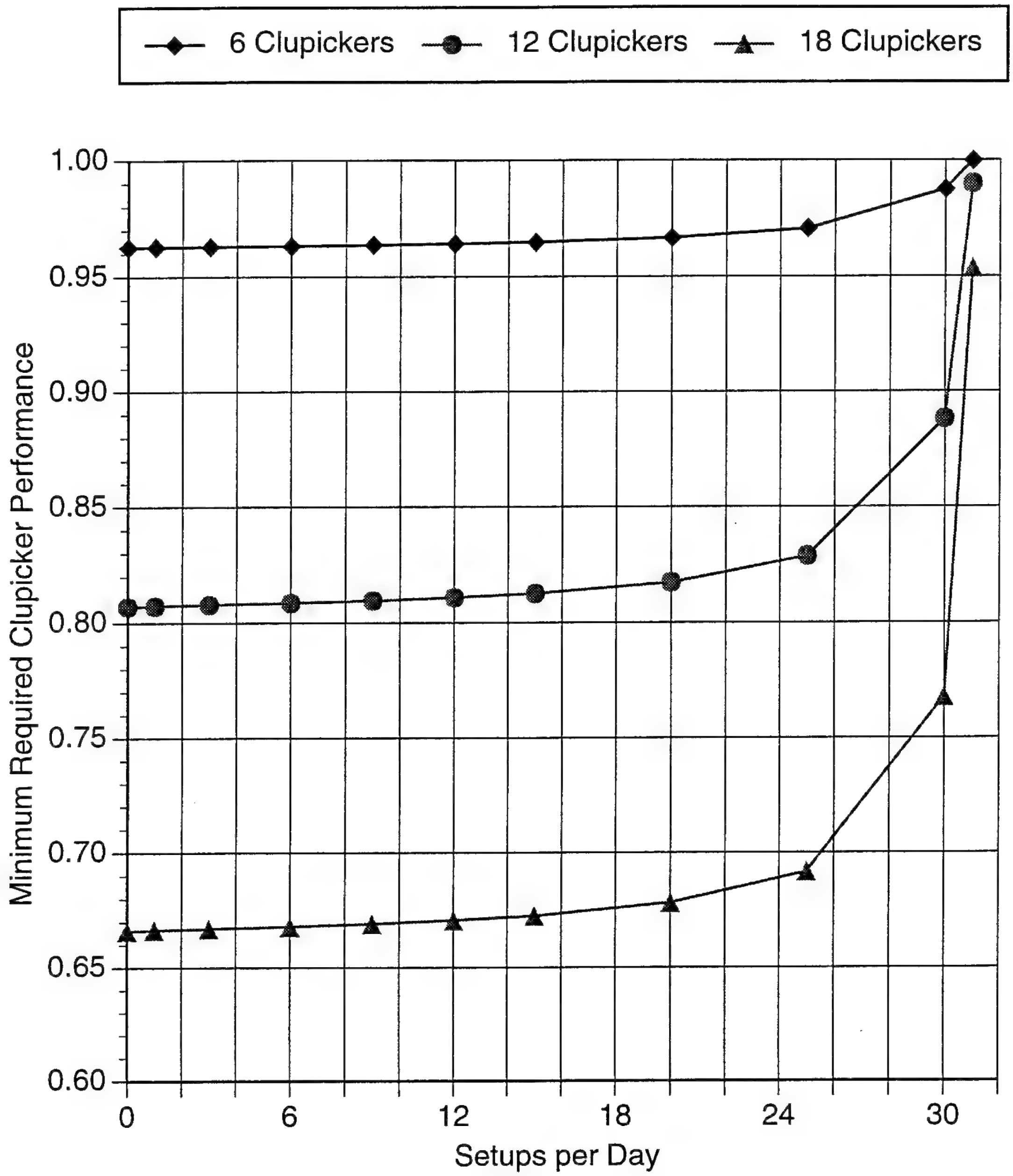
Appendix Q - AMCIA Time Check Data

To ensure that the data in Appendices M and N were reasonable, the Clupicker Program (Appendix J) compared the amount of operator time *available* to correct Clupicker errors (storage register 42) with the time *required* to correct Clupicker errors (storage register 43). The time check was based on equations presented in Chapter 3 and the associated "Time Check" data is presented in Appendix Q. In all the scenarios evaluated, the time available to conduct repairs exceeded the time required to conduct the repairs.

Appendix R - Minimum Clupicker Performance Requirements (based on Time Check Data)

In all of the production scenarios evaluated, the Clupickers produced positive net present values. This is because, in every case, the Clupickers allowed the Hemmers to increase production capacity enough to justify the expense of both the Clupickers and the Hemmers. The only time that production capacity could be jeopardized is when the time required to repair Clupicker related errors exceeds the time available to conduct those repairs.

When the time required to correct Clupicker errors exceeds the time available , the Clupickers create more problems than they solve. In an attempt to answer Question 5, CAR decided to find the minimum Clupicker performance levels that ensure that the time available to conduct repairs just exceeds the time required the to conduct the repairs. Appendix R details the analysis. A graph of the Appendix R data is shown on the next page.



Graph 4-8: Appendix R Data

Graph 4-8 shows many interesting things. First it shows that if the number of setups per day exceeds 15, the minimum Clupicker performance must start improving dramatically for the Clupickers to be cost effective. Next Graph 4-8 shows that for production environments with 12 setups per day or less, the only time six Clupickers would be inadequate is when their *individual* performances dropped below approximately 96.5%.

Several of the companies surveyed by Dr. Clapp's students reported Clupicker performances below 96.5%. Chapter 2 showed that, with the development of a careful setup procedure (including a "Bologna Slicer"), the Original Clupickers can be made to reliably perform at levels above 97%. For those companies who do not feel their Original Clupickers can be made to perform above 96.5% the decision to purchase the Modified Clupickers is easily justifiable, provided the company can take advantage of the added production capacity afforded by the Modified Clupickers. There is another alternative, however, which brings us back to Question 5.

Question 5

Are there other improvements which could make the Loader/Clupicker technology better, i.e. more financially attractive?

Answer 5

Graph 4-8 clearly shows, that the use of grouped Clupickers allows individual Clupicker performances to drop without affecting the overall performance of the machine the Clupickers are attached to. For example: Graph 4-8 plots the minimum performance of twelve Clupickers grouped into six groups with two Clupickers per group. In such a grouping, the *individual* Clupickers can have performance levels as low as 81% and still pick as effective as six Clupickers with individual performance levels of approximately 96.5%. Eighteen Clupickers grouped in to six groups with three Clupickers per group can have individual perform at levels as low as 66.5% and again pick as well as six Clupickers with individual performance levels of approximately 96.5%.

This ability of grouped Clupickers to mask poor individual Clupicker performances, was part of the problem associated with setting up the Clupickers in the original experiment (see Chapter 2). In any event, increasing the number of Clupickers in an automated machine may increase the cost by $2000 per Clupicker, but the AMCIA analyses conducted in Appendices M and N, and the models created in this chapter will probably support the hypothesis that the monetary gains derived from group Clupicker performances can readily offset the cost of the additional Clupickers, provided the company is able to capitalize on the added production capacity created by the improved grouped Clupicker performances.

One other approach might be used to make the Loader/Clupicker technology better. During testing the test team noted that a large percentage of Loader detected mispicks could be corrected simply by releasing the offending plies and repicking them. Although no data was recorded on how mispicks were corrected, repicking was the predominant correction method used. Jet Sew should consider modifying the Loader

controls so that when a mispick condition is sensed the Loader drops the offending plies and automatically attempts to repick the top-most ply. The test team's experience suggests that if the mispick condition persists after three pick attempts, manual intervention is truly required.

5

Chapter 5: Conclusions and Recommendations

From Chapter 2

Table 2-11: Clupicker Performance Data Summary (See Tables 2-6, -7, -9, and -10)			
Clupicker Type	Correction Factors	Individual Picker Performance	
		No Clupicker Interaction	Strong Clupicker Interaction
Original	None	97.41	97.97
	1	**97.51***	98.06
	2	97.14	98.67
	1 and 2	97.23	**98.76**
Modified	None	**98.68**	**99.23**
* Values in bold are the highest values for each Clupicker type.			

From Table 2-11 one can conclude that regardless of whether correction factors are applied or whether device interactions are present or not: For shirting fabrics in general, the Modified Clupickers consistently outperform the Original Clupickers. But, Chapter 2 also shows that a simple a device (a Bologna Slicer) can make troubleshooting of the Original Clupicker sufficiently fast and accurate that in some cases Modified Clupickers may not be required.

From Chapter 3

Before a company can conduct a cost analysis on any piece of equipment, the company must understand how the equipment will affect the manufacturing environment. To prepare for a Clupicker cost analysis:

1. The individual Clupicker performance ratings must be determined. This was done in Chapter 2.
2. The device which limits the Clupicker cycling times must be identified. In Chapter 3 it was shown that the Clupicker processing speed is limited by the Jet Sew Hemmer.
3. The way Jet Sew Hemmers fit into apparel manufacturing environments must be modeled. In Chapter 3 a Jet Sew Hemmer critical production time-path was determined.
4. Time-based information must be added to the critical time-path. The result is a production model for the equipment in

question. In this paper the time-based information applied to a Jet Sew Hemmer (see Figure 3-3). Remember, that Figure 3-3 only applies to one particular manufacturing scenario, however.

5. The basic validity of the production model must be checked. For the Jet Sew Hemmer this was done in the last section of Chapter 3 using one of the program discussed in Appendix J. The check involves determining if the Clupickers create more errors than can be corrected in the time available (see Chapter 3 for a more detailed explanation).

From Chapter 4

Determine if the following conditions apply to you and/or your company:

1. You own a Jet Sew Hemmer with an automatic Jet Sew Loader.
2. You know that hemming is a production bottleneck.
3. You know that you will be able to increase production capacity to nearly match the Hemmer's maximum daily output of 4,500 units per day (see the Direct Labor Worksheet's "Implied change in annual production capacity" heading in Appendix I).
4. You are interested in replacing the Original Clupickers with Modified Clupickers.

If these condition apply, use Equation 4.19 to calculate the net present value of the decision to replace your Hemmer/Loader Original Clupickers with Modified Clupickers.

$$y_1 = \{-1.8477472 \times [CP_{Original} - (1.7223141 \times CP_{Modified}) + 70.7651120]\} \times \left\{ \left[\frac{x_1}{[CP_{Original} + (0.3858896 \times CP_{Modified}) - 171.6396950]} \right] + 0.6522635 \right\}$$

Equation 4.19: NPV of Clupicker Replacement

where

y_1 = The net present value (in millions of dollars) associated with replacing Original Clupickers with Modified Clupickers. Example: $y_1 = 0.991717$ implies an NPV of $991,717.

$CP_{Original}$ = Clupicker $Performance_{Original}$ in percent.

Example: Enter 96.5 for 96.5%. **Do not** enter 0.965 for 96.5%.

$CP_{Modified}$ = Clupicker $Performance_{Modified}$ in percent.

Example: Enter 97.5 for 97.5%. **Do not** enter 0.975 for 97.5%.

x_1 = Number of Setups per Day
Example: Any whole number from 1 to 12. Numbers larger than 12 should not be entered (see discussion of Appendices Q and R, below).

If the conditions listed above do not apply to you check to see if these conditions apply:

1. You are interested in purchasing a Jet Sew Hemmer with an automatic Jet Sew Loader.
2. You know that hemming is a production bottleneck.
3. You know that you will be able to increase production capacity to nearly match the Hemmer's maximum daily output of 4,500 units per day (see the Direct Labor Worksheet's "Implied change in annual production capacity" heading in Appendix I).

If these conditions apply use Equation 4.20, below, to calculate the net present value of the decision to purchase a Jet Sew Hemmer/Loader combination equipped with Modified Clupickers.

$$y_2 = y_1 - Cost_{Hemmer}$$

Equation 4.20: NPV of Jet Sew Hemmer Purchase

where

y_2 = The net present value (in millions of dollars) associated with purchasing a Jet Sew Hemmer equipped with Modified Clupickers. Example: $y_2 = 0.751085$ implies an NPV of $751,085

y_1 = The net present value (in millions of dollars) associated with replacing Original Clupickers with Modified Clupickers from

Equation 4.19 (**see note below**).
Example: y_1 = 0.99717 implies an NPV of $991,717

$Cost_{Hemmer}$ = The Cost of a Jet Sew Hemmer expressed in millions of dollars.
Examples: If a Hemmer costs $75,255 enter 0.0752555.
If a Hemmer costs $752,550 enter 0.7525550.
If a Hemmer costs $7,525,500 enter 7.5255500.

Note: Instead of using $CP_{Original}$ = Clupicker $Performance_{Original}$
use $CP_{Original}$ = Direct Labor Efficiency

For an explanation of how to calculate Direct Labor Efficiency, see Appendix I page I-18.

The net present values generated by Equations 4.19 and 4.20 are most dramatically affected by the Modified Clupicker performance. The Original Clupicker performance has the next greatest impact on net present value, and the number of setups per day has a smaller, but significant, impact on net present value. Worker hourly wages have virtually no impact on the net present value calculations associated with the Clupickers.

If Equation 4.19 or 4.20 generate net present values that seem unreasonably high, use CAR's AMCIA program and Appendix I to conduct your own detailed cost analysis. Complete the AMCIA worksheets in the following order:

1. Company Data Sheet
2. Investment, Installation, and Depreciation Worksheet
3. Direct Labor Worksheet
4. Indirect Labor Worksheet
5. Quality Related Costs Worksheet

Of these five worksheets only the last three contribute to a positive net present value for the complete analysis. Of these three worksheets Direct Labor easily contributes the most while Indirect Labor and Quality Related Costs contribute the least (see the example in Appendix L).

Remember: You can get a free copy of the AMCIA program from Clemson Apparel Research, 500 Lebanon Rd., Pendleton, SC 29670, Phone: 803/646-8454.

Regardless of which method is used to conduct a cost analysis, provided the company can take advantage of the added production capacity, example calculations presented in this paper show that the performance improvements determined in Chapter 2 are sufficient to justify purchasing six Modified Clupickers. It is also shown at the end of Chapter 4 that for the best possible Loader performance each Modified Clupicker should be installed next to an Original Clupicker rather than replacing the Original Clupicker. In this way the side-by-side Clupickers perform as one, and the chances of both Clupickers mispicking simultaneously becomes extremely small.

Despite the favorable cost analyses presented in this paper, however, companies looking to justify Clupicker purchases based on labor savings alone may be disappointed. Discussions at the end of Appendix I's Direct Labor Worksheet show that apparently high Clupicker performance values actually translate into lower of direct labor efficiencies. For example, in Appendix I a Clupicker efficiency of 99.5% translates into a direct labor efficiency of only 84.6% (84.5589% was the calculated value). The reasons for this are explained in detail in Appendix I, but basically the decrease in performance is related to the fact that malfunctioning Clupickers can create errors faster than direct labor can correct those errors.

Also, companies will be disappointed to learn that Hemmer/Loaders require constant human monitoring. There are several reasons for this. First, if the Hemmer/Loader is a production bottleneck plant production capacity is limited by the Hemmer/Loader's performance. Therefore, all efforts must be made to ensure the Hemmer/Loader never stops (or at least stop infrequently). Second, because Clupicker errors occur at random and because Clupicker errors will frequently cause the Hemmer/Loader to stop, someone must watch over the Clupickers at all times. Third, the last fifteen minutes of a production run are particularly critical. If the Clupickers produces a large number of errors at the end of a production run, the time spent correcting those errors may interfere with the setup and running of the next production run (see Chapter 3 for a more detailed explanation). This does not mean development of the Modified Clupickers was a waste of time, however.

The Modified Clupickers will reduce the number of times an operator must correct mispick conditions by giving the Loader's the ability to automatically correct for large fabric variations. The Loader's can also automatically correct mispicks if Jet Sew modifies the Loader's controls so that when a mispick condition is sensed the Loader drops the offending plies and automatically attempts to repick the top-most ply. The test team's experiences suggests that most mispick conditions can be corrected in this fashion, and that in most cases only after two repick failures is manual intervention truly required.

The only condition which the Loader's can not compensate for is poor bundle quality. High bundle quality can be achieved by the following:

1. Use automated cutting equipment to produce cut parts for Clupicker operations. Automated cutters produce more consistent parts than manual cutters.
2. Use a stiffer spreading paper under the Clupicker bundles. The stiffer paper helps reduce bundle distortion during handling.
3. Lift the bundles with two hands to avoid shifting the plies.
4. Lift the bundles on the edges perpendicular to the edge the Clupicker will pick. This ensures that if the plies shift they shift from side-to-side with respect to the Clupickers instead of in and out.
5. If possible keep the Clupicker bundles small. Several small bundles are easier to handle and load than one large bundle.
6. Avoid getting the cutting blade hot. This prevents fusing and minimizes edge fraying. Lower blade temperatures can be achieved by regular sharpening, reduced fabric compression (i.e., weaker vacuum hold-down), forced cooling, blade lubrication, reduced cutting height, and lower cutting speeds.
7. Reduce edge fraying using the cutting blade techniques discussed above and by minimizing contact with the bundle edges.
8. Reduce ply-to-ply attraction by minimizing ply-to-ply shifting and reducing fabric compression. Ply-to-ply shifting promotes surface fiber entanglement and electrostatic attraction. Ply-to-ply shifting occurs mostly during spreading when the plies are not being spread tension-free. Fabric compression occurs when the lower plies are weighed down by the upper plies (i.e., in thick spreads). Compression also occurs on the vacuum bed of automated cutters.
9. If splitter paper has to be used decide if it is better for the Clupickers to process the paper or to mispick, and choose your paper accordingly. Thin flexible paper will pick better than thick stiff paper.
10. Splitter paper can be avoided by reducing the bundle sizes. Remember, production is only as fast as the slowest operation. If the hemming operation is indeed the slowest operation in the plant, reducing the speed of the spreading and cutting operation (by reducing bundle sizes) will have no impact on production throughput.

Any company that understands and follows the recommendations listed above can expect the Modified Clupickers to extend the company's production capacity, even if the daily setup times are

large. (To calculate how much production capacity increases, see the Direct Labor Worksheet's "Implied change in annual production capacity" heading in Appendix I and the Clupicker programs in Appendix J). Increasing a Hemmer/Loader's production capacity is only useful if it avoids a production bottleneck, however. If a production bottleneck is not removed with increased production capacity it means that there was sufficient excess capacity to start with, and additional improvements are not necessary. In other words, improving a hemming operation by purchasing a Jet Sew Hemmer and Loader equipped with Modified Clupickers only makes sense if the hemming operation is a true production bottleneck.

Inter-Office Memorandum

Date:

To:

Reference:

From:

References

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1.2 Pierce, Elroy, Project Manager, Clemson Apparel Research (CAR), interview; 500 Lebanon Rd., Pendleton, SC 29670, Phone: 803/646-8454, August, 1995.

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Major contributions by Beaton, John Robert, and Daniel, Robert Keith, graduate Textile Engineers, NCSU.

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4.1 Schramayr, Ernst, A Proposal to Modify the Jet Sew Shirt Sleeve Feeder, Description of Budget Items Phase II; Jet Sew, P.O. Box 326 Barneveld, NY 13304, September 6, 1990. Phone: 315/896-2683.

4.2 No formal data was taken concerning the Loader's positioning abilities, but from basic experimental observations, variations of up to 3/4" were not uncommon (see Chapter 2 page 6).

I.1 Daniel, Robert Keith, College of Textile, North Carolina State University (NCSU), Enhance the Commercial Acceptance of an Automatic Ply Separation & Feeding System for Apparel Fabrics, page 80; Graduate Faculty of NCSU, Raleigh, NC, October 28, 1991.

I.2 Clapp, Dr. T. G., Professor, College of Textile, North Carolina State University (NCSU), Final Report: Improvement of Clupicker Phase I, DLA900 - 87-0017, DO-0024, page 2; NCSU, Raleigh, NC, January 11, 1993.
Major contributions by Beaton, John Robert, and Daniel, Robert Keith, graduate Textile Engineers, NCSU.

I.3 Daniel, Robert Keith, College of Textile, North Carolina State University (NCSU), Enhance the Commercial Acceptance of an Automatic Ply Separation & Feeding System for Apparel Fabrics, pages 76 - 79; Graduate Faculty of NCSU, Raleigh, NC, October 28, 1991.

APPENDICES

Appendix A - Original Experimental Design

The following experimental design is outlined according to the original experimental design-outline provided in the Fundamental Concepts in the Design of Experiments, Third Edition, by Charles R. Hicks:

I. Experiment
   A. Statement of problem
   B. Choice of response or dependent variable
   C. Selection of factors to be varied
   D. Choice of levels of these factors
      1. Quantitative or qualitative
      2. Fixed or random
   E. How factor levels are to be combined

II. Design
   A. Number of observations to be taken
   B. Order of experimentation
   C. Method of randomization to be used
   D. Mathematical model to describe the experiment
   E. Hypothesis to be tested

III. Analysis
   A. Data collection and processing
   B. Computation of test statistics
   C. Interpretation of results for the experimenter

Each step will be listed below with its associated solution.

I. A. Problem Statement: Which Clupicker system is least affected by fabric variations?

I.B. Response (Dependent) Variable: Mispicks, both no-pick and multi-pick types.

I.C. Factors to be varied (Treatments): Clupicker systems (i.e., three grouped pickers and their associated transfer devices).

I.D. Choice of factor levels: 1) Qualitative
2) Fixed

and Two levels total (i.e. the Old Clupicker system the New Clupicker system).

I.E. Factor combinations: Since this is a single factor experiment there are not factor combinations (see the chart at the end of this design list).

II.A. Number of observations: Based on statistical information given in Tim Clapp's Phase I Clupicker Project Report, and assuming a normal performance distribution, each sample run should consist of at least 7,885 plies (*the experimental units for this experiment are short sleeves*) per feeder section for a statistical alpha (a) of 0.05 and beta (b) of 0.10 with a 10% sensitivity range. Unfortunately, given the speed of the feeder in handling shirt sleeves, processing a single sample would take at least 22.5 hours with the machine running continuously even without a mistake. Constrained by the fact that a work day is eight hours, the sample size will be limited to 2000 plies per feeder section per day. Based on analysis of error degrees-of-freedom and statistical F-tests, and considering a day as a single replication, at least four days of experimentation will be required during which 16,000 plies can be processed.

II.B. Order of Experimentation: See the chart at the end of this design list.

II.C. Method of randomization to be used: Blocking by day (see the chart at the end of this design list).

II.D. Mathematical model

$$Y_{ijk} = m + b_i + t_j + g_k + e_{ijk}$$

Where:

Y_{ijk} ∫ performance value

m ∫ performance mean

b_i ∫ block effect

t_j ∫ treatment effect

g_k ∫ position effect

e_{ijk} ∫ random error

II.E. Hypothesis to be tested: H_0: m = 99.9% new picker efficiency
H1: m £ 99.9% picker efficiency

Since a comparison is being drawn between the old and new pickers, F-tests shall be run according to the chart at the end of this report.

If this experiment is acceptable to the Design Team, the complete experiment, minus data, can be described in the outlined on the next page:

Clupicker Experimental Design

Feeder Position	Day (Replication Blocks) I	II	III	IV
Left	Old Clupicker	New Clupicker	Old Clupicker	New Clupicker
Right	New Clupicker	Old Clupicker	New Clupicker	Old Clupicker

Due to set-up times at least half a day should be allowed to change the picker systems from left to right. This means that for four replications a minimum of six days should be allotted for completion of the experiment. Also, the design shown above allows for additional replications to be added at random allowing for increased experimental sensitivity should differences in Old and New Clupicker performances be difficult to demonstrate.

An Error Mean Square (EMS) Table is given below along with the recommended F-tests.

Clupicker EMS Table

Source		Degrees of Freedom	4 levels Random i	2 levels Fixed j	2 levels Fixed k	EMS
Replications	b_i	3	1	2	2	$s_e + 4(s_b)^2$
Treatments	t_j	1	4	2	0	$s_e + 8f_t$
Positions	g_k	1	4	0	2	$s_e + 8f_g$
Error	e_{ijk}	2	1	0	0	s_e

In each case the correct F-tests are defined as:

$$F = \text{Mean Square}_{\text{Source Effect}} \; \Pi \; \text{Mean Square}_{\text{Random Error}}$$

The math associated with this experiment and other related information shall be developed when Phase II is funded. For the time being, the above information more that adequately describes a complete Clupicker Experimental Design.

Appendix B - Shirt Fabrics Used

Shirt Fabrics Used			
Fabric Description	Stack #1	Stack #2	Total # of Plies
Blue Striped Oxford	34	34	68
Chambray	65	65	130
Dark Blue Broad Cloth	49	49	98
Light Blue Broad Cloth	24	24	48
Light Blue Oxford (Shade #1)*	38	38	76
Light Blue Oxford (Shade #2)*	7	7	14
Light Blue Oxford, Fine	6	6	12
Light Blue Oxford, Stiff	27	27	54
Military Green, AG 415	25	25	50
Peach Oxford (Land's end)	59	59	118
Pink Oxford (Land's end)	44	44	88
Red/Blue Striped Oxford	3	3	6
Red/Grey Striped Oxford	2	2	4
Wendy's	48	48	96
White Broad Cloth	47	47	94
White Oxford (Shade #1)**	47	47	94
White Oxford (Shade #2)**	9	9	18
Yellow Oxford (Land's end)	36	36	72
Totals	570	570	1140

* In handling, it was impossible to distinguish between these two fabrics. In the remaining appendices they are simply referred to as Light Blue Oxford.

** Again, it was impossible to distinguish between these two fabrics. In remaining appendices they are simply referred to as White Oxford.

Appendix C - Bundle Names and Bundle Ply Sequences

Page 1 of 6	Bundle Names			
ID	Chambrey / Chambrey	Dark Blue Broad Cloth / Wendy's	Pink Oxford / White ~~Oxford~~ BROAD	Blue Stripe / Yellow Oxford
Ply #	Bundle #1	Bundle #2	Bundle #3	Bundle #4
001	CHAMBREY	DRK BLU OX	PNK OX	BLU STRIPE
002	LT BLU BROAD	PCH OX	LT BLU OX STIFF	WHT OX
003	PNK OXFORD	WHT OX	PNK OX	CHAM
004	YELLOW OX.	CHAM	LT BLU OX STIFF	PCH OX
005	PEACH OX	PCH OX	WHT BROAD	PNK OX
006	LT BLU OX STIFF	PNK OX	WENDYS	LT BLU BROAD
007	BLU STRIPE OX	PCH OX	LT BLU OX STIFF	YEL OX
008	DK BLU BROAD	WENDYS	MIL GREEN	LT BLU OX STIFF
009	LT BLU OX FINE	RD/BLU STRIPE	WHT OX	DK BLU BROAD
010	WHITE OX	WHT OX	WENDYS	CHAM
011	WENDYS	BLU STR OX	PCH OX	MIL GREEN
012	MIL GREEN	LT BLU OX	LT BLU OX STIFF	WHT OX
013	WHT OX	LT BLU OX FINE	PCH OX	PNK OX
014	CHAMBREY	WHT BROAD	MIL GREEN	PCH OX
015	LT BL OX	WHT OX	PCH OX	BLU STRIPE
016	LT BL OX	LT BLU BROAD	LT BLU BROAD	WHT BROAD
017	WHT BROAD	MIL GREEN	LT BLU OX STIFF	LT BLU OX
018	PINK OX	YEL OX	MIL GREEN	WENDYS
019	WENDYS	CHAM	WHT BROAD	WHT OX
020	PEACH OX	LT BLU OX STIFF	PCH OX	MIL GREEN
021	WHT OX	LT BLU OX	CHAM	CHAM
022	BLU STR OX	DRK BLU BROAD	YEL OX	DRK BLU BROAD
023	BLU OX	PEACH OX	CHAM	LT BLU OX STIFF
024	BLU OX FINE	LT BLU BROAD	BLU STRIPE	YEL OX
025	WHT BROAD	RD/BLU STRIPE	CHAM.	LT BLU BROAD
026	LT BLU BROAD	LT BLU OX STIFF	LT BLU OX STIFF	WENDYS
027	WHT OX	LT BLU OX FINE	CHAM	LT BLU OX
028	YEL OX	PNK OX	WHT BROAD	WHT BROAD
029	GRN MIL	RD/GRY STRIPE	CHAM	BLU STRIPE
030	LT BLU OX STIFF	YEL OX	DK BLU BROAD	PCH OX
031	CHAMBREY	BLU STRIPE OX	CHAM	PNK OX
032	DK BLU BROAD	DK BLU BROAD	LT BLU OX	DRK BLU BROAD

Page 2 of 6	Bundle Names			
ID	Chambrey / Chambrey	Dark Blue Broad Cloth / Wendy's	Pink Oxford / White Oxford	Blue Stripe / Yellow Oxford
Ply #	Bundle #1	Bundle #2	Bundle #3	Bundle #4
033	LT BLU OX	PCH OX	CHAM	LT BLU OX
034	LT BLU BROAD	RD/GRN STRIPE	MIL GREEN	MIL GREEN
035	WENDYS	RD/BLU STRIPE	CHAM	WENDYS
036	YEL OX	BLU STRIPE	WHT OX	WHT OX
037	LT BLU OX STIFF	LT BLU OX FINE	CHAM	CHAM
038	WHT OX	PNK OX	YEL OX	WHT BROAD
039	LT BLU OX	LT BLU BROAD	CHAM	LT BLU OX
040	DRK BLU BROAD	YEL OX	PCH OX	PCH OX
041	WHT BROAD	LT BLU OX STIFF	CHAM	LT BLU BROAD
042	WHT OX	DK BLU BROAD	PNK OX	PNK OX
043	GRN MIL	WHT OX	CHAM	YEL OX
044	PNK OX	WHT OX	YEL OX	BLU STRIPE
045	PCH OX	CHAM	DK BLU BROAD	WHT OX
046	CHAM	WT BROAD	PCH OX	MIL GREEN
047	LT BLU ST OX	WENDYS	CHAM	LT BLU BROAD
048	LT BLU OX	MIL GRN	PNK OX	CHAM
049	LT BLU OX FINE	LT BLU OX	WHT OX	YEL OX
050	LT BLU OX	LT BLU OX	CHAM	DK BLU BROAD
051	DK BLU BROAD	WENDYS	DK BLU CHAM	LT BLU OX STIFF
052	CHAM	WHT OX	PNK OX	WENDYS
053	LT BLU OX STIFF	LT BLU OX	PCH OX	PNK OX
054	MIL GRN	WT BROAD	DRK BLU BROAD	LT BLU OX
055	YEL OX	WHT OX	CHAM	PCH OX
056	WHT OX	MIL GREEN	PNK OX	WHT BROAD
057	LT BLU BROAD	CHAM	PCH OX	BLU STRIPE
058	BLU STR OX	LT BLU OX	CHAM	YEL OX
059	WHT BROAD	PCH OX	DRK BLU BROAD	PNK OX
060	PEACH OX	WHT OX	PCH OX	WHT OX
061	LT BLU OX	CHAM	PNK OX	CHAM
062	PNK OX	PCH OX	WHT OX	PCH OX
063	WHT OX	PNK OX	DK BLU BROAD	PNK OX
064	WENDYS	WENDYS	CHAM	LT BLU BROAD
065	PNK OX	WHT OX	YEL OX	PNK OX
066	PEACH OX	MIL GREEN	PNK OX	YEL OX
067	CHAM	CHAM	PCH OX	PCH OX

Page 3 of 6	Bundle Names			
ID	Chambrey / Chambrey	Dark Blue Broad Cloth / Wendy's	Pink Oxford / White Oxford	Blue Stripe / Yellow Oxford
Ply #	Bundle #1	Bundle #2	Bundle #3	Bundle #4
068	WHT OX	LT BLU OX STIFF	DRK BLU BROAD	LT BLU OX STIFF
069	CHAM ✓	WHT BROAD	CHAM	BLU STRIPE
070		DK BLU BROAD	WHT OX	WHT OX
071		LT BLU OX STIFF	BLU STR	WENDYS
072		BLU STRIPE	PCH OX	MIL GREEN
073		PCH OX	YEL OX	LT BLU OX
074		YEL OX	PNK OX	CHAM
075		LT BLU BROAD	BLU STRIPE	WHT BROAD
076		PNK OX	PCH OX	DRK BLU BROAD
077		PCH OX	YEL OX	LT BLU BROAD
078		YEL OX	PNK OX	PNK OX
079		LT BLU OX STIFF	WENDYS	YEL OX
080		BLU STRIPE	WHT OX	PCH OX
081		WHT BROAD	CHAM	LT BLU OX STIFF
082		DK BLU BROAD	DR BLU BROAD	BLU STRIPE
083		CHAM	WENDYS	DK BLU BROAD
084		LT BLU OX	WHT OX	CHAM
085		MIL GREEN	CHAM	MIL GREEN
086		WHT OX	DK BLU BROAD	WHT OX
087		WENDYS	PNK OX	WENDYS
088		WHT OX	WHT OX	LT BLU OX
089		WENDYS	BLU STRIPE	WHT BROAD
090		MIL GREEN	WHT OX	WENDYS
091		CHAM	CHAM	WHT OX
092		LT BLU OX	WHT OX	MIL GREEN
093		DRK BLU BROAD	YEL OX	LT BLU OX
094		WHT BROAD	BLU STRIPE	CHAM
095		LT BLU BROAD	PNK OX	WHT BROAD
096		PNK OX	CHAM	DK BLU BROAD
097		YEL OX	WENDYS	BLU STRIPE
098		PCH OX	WHT OX	LT BLU OX
099		LT BLU OX STIFF	WENDYS	PCH OX
100		BLU STR	DRK BLU BROAD	YEL OX
101		DK BLU BROAD	CHAMBREY	PNK OX
102		WENDYS	LT BLU OX	LT BLU BROAD

Page 4 of 6	Bundle Names			
ID	Chambrey / Chambrey	Dark Blue Broad Cloth / Wendy's	Pink Oxford / White Oxford	Blue Stripe / Yellow Oxford
Ply #	Bundle #1	Bundle #2	Bundle #3	Bundle #4
103		LT BLU OX	WHT BROAD	BLU STRIPE
104		WHT BROAD	LT BLU OX	PCH OX
105		BLU STRIPE	YEL OX	PNK OX
106		PCH OX	DRK BLU BROAD	LT BLU OX STIFF
107		WHT OX	PNK OX	YEL OX
108		CHAM	YEL OX	LT BLU BROAD
109		DRK BLU OX	BLU STRIPE	WHT BROAD
110		YEL OX	LT BLU OX	LT BLU OX
111		PNK OX	PNK OX	WHT OX
112		LT BLU BROAD	LT BLU OX	WENDYS
113		PCH OX	PCH OX	DRK BLU BROAD
114		BLU STR	LT BLU OX	CHAM
115		WENDYS	WHT OX	MIL GREEN
116		WHT OX	WENDYS	WHT OX
117		CHAM	WHT BROAD	LT BLU BROAD
118		LT BLU OX	CHAM	PCH OX
119		DK BLU BROAD	DRK BLU BROAD	LT BLU OX STIFF
120		WHT BROAD	WENDYS	WHT BROAD
121		YEL OX	DRK BLU BROAD	CHAM
122		LT BLU BROAD	CHAM	WHT OX
123		PNK OX	LT BLU OX	WHT OX
124		PCH OX	WENDYS	WENDYS
125		BLU STRIPE	WHT BROAD	MIL GREEN
126		WHT BROAD	WENDYS	LT BLU OX
127		LT BLU OX	CHAM	DRK BLU CHAM
128		WENDYS	WENDYS	BLU STRIPE
129		WHT OX	DRK BLU BROAD	YEL OX ✓
130		CHAMBREY	WENDYS	
131		DK BLU BROAD	LT BLU OX	
132		PNK OX	WENDYS	
133		LT BLU BROAD	YEL OX	
134		WHT OX	WENDYS	
135		CHAM	WHT OX	
136		DK BLU BROAD	LT BLU OX	
137		WHT BROAD	CHAM	

Page 5 of 6	Bundle Names			
ID	Chambrey / Chambrey	Dark Blue Broad Cloth / Wendy's	Pink Oxford / White Oxford	Blue Stripe / Yellow Oxford
Ply #	Bundle #1	Bundle #2	Bundle #3	Bundle #4
138		LT BLU OX	WHT BROAD	
139		WENDYS	DRK BLU BROAD	
140		LT BLU BROAD	WHT OX	
141		PNK OX	CHAM	
142		PCH OX	WENDYS	
143		BLU STRIPE	LT BLU OX	
144		PNK OX	WHT BROAD	
145		WENDYS	CHAM	
146		PCH OX	DRK BLU BROAD	
147		LT BLU OX	PCH OX	
148		BLU STRIPE	PNK OX	
149		WHT BROAD	DRK BLU BROAD	
150		DRK BLU BROAD	BLU STRIPE	
151		LT BLU OX STRIPE	DRK BLU BROAD	
152		CHAMBREY	WENDYS	
153		YEL OX	WHT OX	
154		MIL GREEN	CHAM	
155		WHT OX	WHT BROAD	
156		LT BLU BROAD	WENDYS	
157		MIL GREEN	PNK OX	
158		YEL OX	PCH OX	
159		CHAM	YEL OX	
160		LT BLU OX STRIPE	DRK BLU BROAD	
161		DK BLU BROAD	WHT BROAD	
162		WHT BROAD	WENDYS	
163		BLU STRIPE	DK BLU BROAD	
164		LT BLU OX	WHT OX	
165		PCH OX	WENDYS	
166		WENDYS	WHT BROAD	
167		PNK OX	LT BLU OX	
168		WENDYS ✓	WHT BROAD	
169			WENDYS	
170			WHT BROAD	
171			CHAM	
172			WHT BROAD	

Page 6 of 6	Bundle Names			
ID	Chambrey / Chambrey	Dark Blue Broad Cloth / Wendy's	Pink Oxford / White Oxford	Blue Stripe / Yellow Oxford
Ply #	Bundle #1	Bundle #2	Bundle #3	Bundle #4
173			WENDYS	
174			WHT BROAD	
175			LT BLU OX	
176			WHT BROAD	
177			CHAM	
178			PCH OX	
179			DK BLU BROAD	
180			WHT BROAD	
181			WENDYS	
182			WHT OX	
183			LT BLU OX	
184			WHT BROAD	
185			CHAM	
186			WHT BROAD	
187			DK BLU BROAD	
188			WHT BROAD	
189			YEL OX	
190			WHT BROAD	
191			BLU STRIP	
192			WHT BROAD	
193				
194				
195				
196				
197				
198				
199				
200				
201				
202				
203				
204				
205				
206				
207				

Appendix D - Initial Experimental Results

Initial Experiment 1 - Page 1 of 2

— PRE EXPERIMENT SETUP TESTS —

Person Running the Test: TONY & MADHU	Date: 7/10/95
Time Started: 11:30	Time Finished:
GENERAL BUNDLE ID: CHABREY (RUN #1)	PAGE 1 of 2

PLY #'S	BUNDLE IN LEFT FEEDER BANK (A) or B (Circle One) — Error: TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom	BUNDLE IN LEFT FEEDER BANK (B) or A (Circle One) — Error: TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom
12	DP	5	LIGHT BLUE			
13			WHT OX.			
14			YEL OX.			
16	DP	5	MIL GRN			
17			LT BL OX			
18			CHAMBRAY			
18				DP	3, 2	CHAMBRY
19						DK BLUE
20						BLU OX
	DP	4, 5	DRK BL			
20			LT BL OX			
20						
21			LT BL LPSED			
26	MP	6 4	PEACH			
27			MIL GRN			
28			PINK			
31	MP	4	BL LA BDS ENDON			
32			LT BL OX STIK			
32			WT OX			
33	MP	4	LT OX			
34			YEL OX			
35			WIDDYS			
36	MP	6 4	LANDS BL OX			
37			DRK BLU			
38			CHAMBRAY			
39	MP	6 4	LT BL OX	DP	3 2	LT BL OX
40			MIL GN			MIL GN
41			YEL OX			YEL OX
42	MP	4	WHT OX			
43			BLU			
			WT			
	DP	5	LT BL BRD			
			WT BROAD			
			LT BL FINE			

DRK [illegible]

Initial Experiment 1 - Page 2 of 2

Person Running the Test: TONY & MADHU			Date: 2/11/95			
Time Started: 9:30 AM			Time Finished: 4:30 PM			
GENERAL BUNDLE ID: CHAMBRET (RUN 01)					PAGE 2 of 2	
	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN LEFT FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom
44			WT BROAD			
45	MP	4	LT BL FINE			
46			LT BL OX			
47			BLST			
48	DP	5	WT OX			
49			PCH OX			
49			PCH OX			
50	DP	5	WENDYS			
51			PINK OX			
50			PCH OX			
51	DP	5	PINK OX			
52			WT BROAD			
53			LT BL OX			
54	MP	6 4	CHAMBRY			
55			WT OX			
56			MILCN.			
57	DP	5	WENDYS			
58			WT OX			
58		6 4	WT OX			
59	MP	5	LT BL FINE			
60			DRK BLU			
	67 PLIES					
	69 PLIES	ACTUAL				

DRC

1ST TRY — SO BAD

Person Running the Test TONY ASPLAND			Date 7/12/95			
Time Started THIS PAGE 8:30 AM			Time Finished THIS PAGE 9:00 AM			
GENERAL BUNDLE ID CHAMBREY (~~CHA~~ RUN #2)						PAGE 1 of
69 PLIES	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN LEFT FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom
1			CHAMBRE			
2	DP	4	LT BLU BROAD			
3						
5			PEACH OX			
6	DP	4	LTBLU OX STIFF			
7			BLU STRIPE			
8			DRK BLU			
9	DP	4	LTBLU OX			
10			WHT OX			
12	DP	4	MIL GRN			
13			WHT OY			
12			MIL GN			
13	DP	4	WHT OY			
14			CHAMBREY			
13			WHT OY			
14	DP	4	CHAMBREY			
15			LTBL OX			
14			CHAMBREY			CHAMBREY
15			LTBLU OX	DP	~~8~~ 2	LT BLU OX
16			LTBLU OX			LTBLU OX
16			LT BLU OX			
17	DP	4	WT BROAD			
18			PINK OX			
18			PINK OX			18 PINK OX
19	DP	4	WENDYS	DP	~~8~~ 3	19 WENDYS
20			PEACH ~~WT~~ OX			20 PEACH ~~WHT~~ OX
19			WENDYS			WENDYS
20			PEACH ~~WT~~ OX	DP	3	PEACH ~~WH~~ WHT OY
21			WT OX			WHT OX
21			WT OX			
22	DP	4	BL STR	~~DP~~		
23			LT BLU OX			
22			BLU STR			
23	DP	4	LT BLU OX			
24			LTBLU FINE			

PRK

Initial Experiment 2 - Page 2 of 3

Person Running the Test			Date
TONY ASPLAND			7/12/95
Time Started THIS PAGE @ 9:00 AM		Time Finished 10:30 AM	
GENERAL BUNDLE ID CHAMBRAY			PAGE 2 of

PLY #'S	BUNDLE IN LEFT FEEDER BANK A or B (Circle One) — Error: TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom	BUNDLE IN LEFT FEEDER BANK B or A (Circle One) — Error: TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom
24			LT BLU FINE			
25	DP	4	WT BROAD			
26			LT BLU BROAD			
25			WT BROAD			
26	DP	5	LT BLU BROAD	DP	2 3	
27			WHT OX			
26			LT BLU BROAD			
27	DP	5 4	WHT OX			
28			YEL OX			
31			~~LT BLU OX STIFF~~	CHAMBRAY		CHAMBRAY
32	MP	4	DRK BL	DP	3, 2	DRK BL
33			LT BLU OX STIFF			LTBL OX STIFF
32						
33	DP	5	LT BLU OX STIFF			
34			LT BLU BROAD			
	MP	4				
34	DP	5, 6	LT BLU BROAD			
35			WENDYS			
34			LT BLU BROAD			LT. BLU BROAD
35	DP	5, 6	WENDYS	DP	2	WENDYS
36			YELLOW OX			YELLOW OX
35			WENDYS			
36	MP	4	YELLOW			
37			LT BLU STIFF OX			
36	DP	4	YEL OX			
37	MP	5	LT BLU STIFF OX			
38			WT OX			
38			WT OX			
39	MP	5	LT BLU STIFF OX			
40			DK BLU			
39			LT BLU STIFF OX			
40	MP	4	DK BLU			
41			WT BROAD			
44			PINK OX			
45	D.P	5, 6	PEACH OX			
46			CHAMBRAY			

Person Running the Test: Tony Aspland			Date: 7/12/95			
Time Started: 10:30 Am			Time Finished:			
GENERAL BUNDLE ID: Chambray					PAGE 3 of	
	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN LEFT FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom
45 46 47	DP	6,5	~~[illegible]~~ Peach ox Chambray Blue Stripe			
	Run	Ter	min	ated		
	Machine	Adj	usted	Using	only white	Bundle
	Experiment		Resu	med	on	Chambray Bundle
0				DP	1,2	[illegible]
13	DP	5				

Appendix E - Diagnostic Test Results

Diagnostic Test 1 - Page 1 of 1

Person Running the Test: Tony		Date: 7/12/98
Time Started: 1:00 PM	Time Finished: 3:00 PM	
GENERAL BUNDLE ID: WHITE #1		PAGE 1 of 1

PLY #'S	BUNDLE IN LEFT FEEDER BANK ~~A or B (Circle One)~~ A			~~BUNDLE IN LEFT FEEDER BANK~~ * ~~B or A (Circle One)~~ A		
	Error			Error		
	TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom
~~10~~ 11	MP	3	~~10~~	MP	4,5	100
16	MP	3		MP	6	105
22	DP	5		MP	~~6,5~~ 6,5	115
24	DP	5		MP	6,5	118
32	DP	6		MP	6,5	122
34	DP	5		DP	4	125
~~40~~	MP	5		DP	5	126
40	DP	4		129	PLIES TOTAL	
54	MP	5		*NO	MISPICK	
55	MP	5		ON PICKER	MODIFIED SIDE	
	MP	5				

PRE TRIAL

Diagnostic Test 2 - Page 1 of 2

Person Running the Test		Date
A 7A		7/12/95
Time Started 3:15 Pm	**Time Finished**	
GENERAL BUNDLE ID WHITE #2		**PAGE** 1 of 2

PLY #'S	BUNDLE IN LEFT FEEDER BANK A or B (Circle One) — Error: TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	BUNDLE IN LEFT FEEDER BANK B or A (Circle One) — Error: TYPE mispick doublepick other	PICKER # (~~6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
10	DP	4				
12	DP	4				
13	DP	4				
			44	DP	2	
			47	DP	2	
80	DP	4		DP	2	80
				DP	2	81
84	DP	~~2~~ 4,5		DP	2	84
86	DP	5		DP	2	86
87	DP	6 5 4		DP	2	87
	~~DP~~	~~5~~		DP	2	88

PRE TRIAL

Diagnostic Test 2 - Page 2 of 2

Person Running the Test AZA				Date 7/12/95	
Time Started ~~3~~ 4:00			Time Finished		
GENERAL BUNDLE ID WHITE #2					PAGE 2 of 2

PLY #'S	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN LEFT FEEDER BANK B or A (Circle One)		
	Error			Error		
	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
90	DP	5				
95	DP	5,4				
102	DP	6,5				
103	DP	6,5				
106	DP	5,4				

PRE TRIAL

Diagnostic Test 3 - Page 1 of 1

2ND TRY   PICKERS 4&5 BAD

Person Running the Test: ADA	Date: 7/13/95
Time Started: THIS PAGE 10:30	Time Finished: THIS PAGE 11:00
GENERAL BUNDLE ID: CHAMBREY RUN #3	PAGE 1 of

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN LEFT FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
03	DP	4				
36	DP	4				
38	DP	5				
	DP	4				
	DP	4				
	DP	4				
	DP	4				
	DP	4				
	DP	4				
— 60 PCS —						

PRE

Appendix F - Pre-experimental Calibration Test

Pre ~~Ex~~ Experiment Calibration Test

Person Running the Test AJA	Date 7/12/95
Time Started 11:00 AM	Time Finished
GENERAL BUNDLE ID WHITE	PAGE 1 of

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN LEFT FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
		124 PLIES		NO	MISPICKS	
221	DP	5				
486	DP	4				
		625 PLIES		NO	MISPICKS	
		750 PLIES		NO	MISPICKS	
862	DP	6				
	1000	PLIES	RUN	NO	MISPICKS	

Pre

Appendix G - Actual Experimental Results

Bundle 1 - Page 1 of 2

OFFICIAL BUNDLE #1

Person Running the Test	ATA	Date	7/15/95
Time Started	11:30 AM	Time Finished	1:00 PM
GENERAL BUNDLE ID	CHAMBRAY 15 RICHS	PAGE	1 of 2

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~) B	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1) A	PLY top (# + desc) offending bottom
07			BLU STR			
08	MP	6	DK BLU			
09			LT BLU FINE			
80			WT OX			
81	MP	5	CHAMBRAY			
	A				B	
66			YEL OX			
67	MP	5	PINK OX			
68			LT BLU BROAD			
	B				A	
07			BLU STR			
08	MP	4	DK BLU			
09			LT BLU FINE			
50			LT BLU OX			
18	MP	5	DK BLU			
52			CHAMBRAY			
	A				B	
18			CHAMBRAY			
19	MP	4	DK BLU			
20			LT BLU OX			
63			BL ST			
64	MP	5	STIFF OX			
65			PEACH OX			

(9 PLIES) ✓

Person Running the Test	AJA			Date	7/15/95	
Time Started	1:30 PM		Time Finished			
GENERAL BUNDLE ID	CHAMBRET					PAGE 2 of 2
	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN LEFT FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
		B			A	
40	DP	5	DK BLU			
41			WT BREAD			
42			WT GY			
57	DP	6, 5	LT BLU BREAD			
58			BL STR			
59			WT BREAD			
63	DP	6 5	WT GY			
64			WEDDINGS			
65			PI WHT			

OFFICIAL BUNDLE #2

Person Running the Test	Tony d'Hacha	Date	July 15 - 1995
Time Started	3:15 pm (1)	Time Finished	3:55 pm
GENERAL BUNDLE ID	DARK BLUE / WENDYS	RIGHT	PAGE 1 of 2

	BUNDLE IN LEFT FEEDER BANK (A) or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK (B) or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
1	MP	4	Dk Blu Peach ox	MP	2	Dk BL Peach ox
7 08 9	MP	654	Wendys RD/BLU Stripe WT OX	MP	321	Wendys RD/BLU Stripe WT OX
18 19 20	MP	6	Lt blue ox Dark blue White ox		2, 1	Lt blue ox Dark blue White ox
21 22 23	MP	6, 5	Lt blue broad cloth RD/Blue Stripe Lt Blue ox stiff			
24 25 26	MP	6, 5, 4	Pink ox RD/Grey Stripe Yellow ox	MP	2, 1	Pink ox RD/Grey Stripe Yellow ox
28 29 30	MP	6	Peach Rd/Grey Stripe Rd/Blue stripe	MP	1	Peach Red/Grey Stripe Red/Blue Stripe
29 30 31	MP	4	Red/Grey Stripe Red/Blue Stripe Blue stripe			
34 35 36	MP	6, 4	Lt Blue stiff ox Dark blue White ox			
85 86 87	MP	6	Lt blue ox Dark blue White broad cloth			
37 136 139	DP	4	Pink ox Wendy's Peach	DP	1	Pink ox Wendy's Peach
	TOTAL	168 PLIES				

Person Running the Test	ADA	Date	7/15/95
Time Started	4:05 pm (2)	Time Finished	4:45 pm
GENERAL BUNDLE ID	WENDY'S / DK BLU	PAGE	2 of

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN LEFT FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
07	MP	6	White broad clth			
08			Dark blue			
09			Lt blue ox Stiff			
18	~~MP~~		Lt blue ox stiff	MP	3	Lt blue ox/stiff
19			Dark blue			Dark blue
20						White broad clth
32	MP	6	White broad clth			
33			Dark blue			
34			Chambray			
37				MP	2	Pink ox
38						Dark blue
39						Chambray
50				MP	3, 2, 1	White broad clth
51						Dark blue
52						Lt blue ox Stiff
60	MP	6	Yellow ox			
61			Dark blue			
62			Chambray			
68	MP	6	Wendy's			
69			Dark blue			
70			blue Strip Clth			
76	MP	6	White broad clth			
77			Dark blue			
78			Lt blue ox			
124	~~DP~~			DP	3	Lt blue ox Stiff
125			Mil Green			Mil Green
126			Wendy's			Wendy's
131	~~DP~~			DP	3	White ox
132						Dark blue
133						Lt blue ox Stiff
138	MP	6	blue stripe			
139			Rd/blue Stripe			
140			Rd/Grey stripe			
148	DP	5	Rd/blue stripe			
149			Lt blue brd clth			
150			Peach			
172	~~MP~~			MP	3, 2, 1	Red/blue stripe
173						Dark blue
~~174~~						

Person Running the Test A 74 F MN

Date July/15/95

Time Started 5:00 pm (3)

Time Finished 5:45

GENERAL BUNDLE ID Dark blue / Wendy1

PAGE of

	BUNDLE IN LEFT FEEDER BANK (A) or B (Circle One)			BUNDLE IN LEFT FEEDER BANK (B) or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
08			W BN TSS			
09	MP	6	R/B STRIPE		MP/	
10			WT OX			
			LT BL OX			LT BL OX
2	MP	6, 4	DRK BLU	MP	1	DK BLU
			R/B STRIPE			R/B STRIPE
25			LT BL BROAD			
26	MP	6, 5, 4	R/B STRIPE			
27			LT BLU STIF			
28			PINK OX			
29	MP	6 4	RD/GY STRIPE			
30			YEL OX			
31			BL STR			
32	MP	4	DK BLU			
33			WT OX			
33			PEA GN			
34	MP	6	RD/GRY STRIPE			
35			RD/BL STR.			
41			LT BL OX STIFF			
42	MP	4, 6	DK BLU			
43			WT OX			
69			WT BROAD			
70	MP	4	DK BL			
71			LT BL STIFF			
81			WT BROAD			
82	MP	6, 4	DK BLU			
83			CHAMBRAY			
118			LT BL OX STIFF			
119	MP	4	DK BLU			
120			WT BROAD			
123			BL STR			
126	MP	6	WT BROAD			
127			LR L/B STIFF			
163			BL STRIPE			
164	MP	5	LT BLU OX			
165			PEAGN OX			

168

Person Running the Test A24 MN		Date 7/12/95	
Time Started 6:00 PM (4)		Time Finished	
GENERAL BUNDLE ID WENDYS / DARK BLU RIGHT			PAGE of

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
06			BL STRIPE			
07	MP	6	WT BROAD			
08			DK BLU			
18						LT BL STIFF
19	,			MP	2 1	DK BLU
20						WT BROAD
32			WT BROAD			WT BROAD
33	MP	6, 4	DRK BLU	MP	3, 2, 1	DK BLU
34			CHAMBREY			CHAMBRAY.
37			PINK OX			PINK OX
38	MP	6	DK BLU	MP	2 1	DRK BLU
39			CHAMBREY			CHAMBREY
47			WT BROAD			WT BROAD
48	MP	4	DK BLU	MP	1	DK BLU
49			LT BLU OX STIFF			LT BL OX STIFF
59						YEL
60				MP		DK BLU
61						CHAMBREY
98			LT BL STIFF OX			
99	MP	4	DRK BLU			
100			WT BROAD			
126			WT OX			
127	MP	4	DK BLU			
128			LT BLU STIFF			
						RD/BL STRIPE
				MP	3	WENDYS
						PEACH
			168			PEACH
			169	MP	1,23	DK BLU

168

Person Running the Test	AZA & MN	Date	7/12/98
Time Started	6:40 (5)	Time Finished	7:15 pm
GENERAL BUNDLE ID	WENDYS / DRK BLU RIGHT	PAGE of	

PLY #'S	BUNDLE IN LEFT FEEDER BANK (A or B (Circle One)) — Error: TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	BUNDLE IN ~~LEFT~~ FEEDER BANK (B or A (Circle One)) — Error: TYPE mispick doublepick other	PICKER # (~~6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
1	MP	4	DK BLU			
2			YEL			
8			WENDYS			WENDYS
9	MP	654	RD/BL STRIPE	MP	1	RD/BL STRIPE
10			WT OX			WT OX
21						LT BL OX
22				MP		DK BLU
23						WT OX
24			LT BL BROAD			LT BLU BROAD
25	MP	6, 5	RD/BLU STR	MP	1	RD/BL STR
26			LT BL OX STIFF			LT BL OX STIFF
28			PINK OX			PINK OX
29	MP	654	RD/GRY STR	MP	1	RD/GY STR
30			YEL			YEL
31			BL STR			
32	MP	4	DK BLU			
33			WT OX			
34			PEACH			PEACH
35	MP	6,5,4	RD/GRY			RD/GRY
36			RD/BLU			RD/BLU
34			RD/GRA			
35	MD	4	RD/BL			
36			BLU STR.			
41			DK LT BLU			
42	MP	6, 4	DK BLU			
43			WT OX			
80			~~WT BROAD~~	BLU STR.		
81	DP	6	WT BROAD			
82			DK BLU			
92			LT BLU OX			
93	MP	4	DK BLU			
94			WT BROAD			
165			Peach			
166	DP	5	Wendys			
167			Pink ox			

Total 168 ?

OFFICIAL BUNDLE #3

Person Running the Test	ATA + MN	Date	7/12/95
Time Started	7:20 PM	Time Finished	7:50 PM.
GENERAL BUNDLE ID	PNK/WHT (1)	PAGE	1 of 10

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN LEFT FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
29			Chambray			
30	MP	4	Dark blue			
31			Chambray			
53						Peach
54				MP	3, 2	Dark blue
55						Chambray
58			Chambray			
59	MP	4	Dark blue			
60			Peach			
62			White ox			
63	MP	4	Dark blue			
64			Chambray			
67			Peach			Peach
68	MP	4	Dark blue	MP	2	Dark blue
69			Chambray			Chambray
81			Chambray			Chambray
82	MP	4	Dark blue	MP	2	Dark blue
83			Wendy			Wendy
85			Chambray			
86	MP	4	Dark blue			
87			Pink ox			
99			Wendy			
100	MP	4	Dark blue			
101			Chambray			
105						Yellow ox
106	~~M~~			MP	2	Dark blue
107						Pink ox
128			Wendy			
129	MP	4	Dark blue			
130			Wendy			
148			Pink ox			
149	MP	4	Dark blue			
150			blue stripe			
188			White bread cloth			
189	MP	5	Yellow ox			
190			White bread cloth			
191	~~MP~~			MP	2	Blue stripe
192						White bread cloth

192 PLIES ✓

Person Running the Test A JA & MN				Date 7/15/95		
Time Started 8:00 PM				Time Finished		
GENERAL BUNDLE ID Pink/White				(2) SEE - LEFT PACK		PAGE 2 of 10
	BUNDLE IN LEFT FEEDER BANK (A) or B (Circle One)			BUNDLE IN LEFT FEEDER BANK (B) or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
4			Yellow			
5	MP	6	White brd clth			
6			Dark blue			
12			Wendys			
13	MP	6	White brd clth			
14			Dark blue			
13						White brd clth
14				MP	2	Dark blue
15						White ox
29			White ox			
30	MP	6	Dark blue			
31			Wendys			
32			White brd clth			
33	MP	6	Dark blue			
34			Yellow			
41			Wendys			
42	MP	6, 4	Dark blue			
43			Blue stripe			
43			Blue Stripe			
44	MP	4	Dark blue			
45			Pink			
46			Peach			
47	MP	4	Dark blue			
48			Chambray			
53			White ox			White ox
54	MP	6, 4	Dark blue	MP	2, 1	Dark blue
55			White brd clth			White brd clth
63						Wendys
64	~~MP~~			MP	2	Dark blue
65						Wendys
68			White brd clth			
69	DP	6	Wendys			
70			Lt blue ox			
72			Dark blue			
73	DP	6	Wendys			
74			Dark blue			

Cont'd

Person Running the Test					Date 7/15/95	
Time Started 8:00 PM				Time Finished		
GENERAL BUNDLE ID Pink/Whit ② Cont. RIGHT						PAGE 3 of 10
	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
75	DP	6	Chambray			
76			White bd cloth			
77			Wendys			
86	MP	6, 5, 4	Pink ox			
87			Dark blue			
88			Yellow			
92	MP	4	Chambray	MP	2	Chambray
93			Dark blue			Dark blue
94			Wendys			Wendys
106	MP	4	Pink ox			
107			Dark blue			
108			Chambray			
124	MP	4	Chambray			
125			Dark blue			
126			Peach			
138	MP	4	Chambray			
139			Dark blue			
140			Peach			
172				DP	3, 2, 1	Yellow
173						Chambray
174						Peach
182	DP	6, 5	Peach	DP	3	Peach
183			Wendys			Wendys
184			White ox			White ox
184				DP	3, 2, 1	Wht ox
185						Hvl Green
186						Lt blu ox Stry

Total 192 PLIES

Person Running the Test	AJA + MN	Date	7/13/95
Time Started	8:20 AM	Time Finished	84
GENERAL BUNDLE ID	PINK / WHT 3 SEGMENT TAIL	PAGE	4 of 10

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN ~~LEFT~~ RIGHT FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
50			CHAMBRAY			CHAMBRAY
51	MP	6,4	DK BLU	MP	2	DK BLU
52			PINK OX			PINK OX
62						WT OX
63				MP	2	DK BLU
64						CHAMBRAY
85			CHAMBRAY			
86	MP	6,4	DK BLU			
87			PINK OX			
118			CHAMBRAY			
119	MP	4	DK BLU			
120			WENDYS			
131			BL OX			
132	DP	5	WENDYS			
133			YEL OX			
141			CHAMBREY			
142	DP	5	WENDYS			
143			LT BL OX			
151			DK BLU			
152	DP	5	WENDYS			
153			WHT OX			
154			CHAMBRAY			
155	DP	4	WHT BROAD			
156			WENDY			
165			WENDYS			
166	DP	5	WH BROAD			
167			LT BL OX STRIPE			
167			LT BL OX STRIPE			
168	DP	4,5	LT BROAD			
169			WENDYS			
171			CHAMBREY			
172	DP	4,5	WT BROAD			
173			WENDYS			
180			WT BROAD			
181	DP	4.5	WENDYS			
182			WT OX			

Person Running the Test: A7A + MN	Date: 7/13/95
Time Started: 8:20	Time Finished: 8:40
GENERAL BUNDLE ID: (3 cont)	PAGE 5 of 10

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN LEFT FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # ~~(6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
189 190 191	MD	6 5 1	YEL OX WT BROAD BLUST			

Person Running the Test	ATA HAN			Date	7/13/95	
Time Started	9:00 AM			Time Finished	9:45 AM	
GENERAL BUNDLE ID	PINK/WHT (4) (3 PAGES) HIGH					PAGE 6 of 10

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4,~~ 3, 2, 1)	PLY top (# + desc) offending bottom
5			White brd clth			White brd clth
6	MP	6, 4	Dark blue	MP	3, 2, 1	Dark blue
7			White brd clth			White brd clth
13			WT BRD			
14	MP	6, 4	DRK BLU			
15			WT OX			
29						WT OX
30				MP	1, 2	DK BLU
31						WENDYS
32			WT BROAD			
33	MP	4	DK BLU			
34			YEL OX			
41			Wendys			Wendys
42	MP	4	Dark blue	MP	2	Dark blue
43			Blue stripe			Blue Stripe
43			blue stripe			
44	MP	4	Dark blue			
45			Pink OX			
63						WENDYS
64				MP	3 2	DRK BLU
65						WENDYS
73			WENDYS			
74			DRK BLU			
75			CHAMBRET			
106			PINK			
107	MP	4	DRK BLU			
108			CHAMBRE			
142			DRK BLU			
143	DP	5	CHAMBREY			
144			WT OX			
149			YEL OX			
150	DP	5	CHAMBRET			
151			PINK OX			
151			PINK			
152	DP	5	CHAM			
153			PEACH			

Person Running the Test	ADA + MN	Date	7/13/95
Time Started	9:00 AM	Time Finished	9:45 AM
GENERAL BUNDLE ID	PINK/WT	4 82 083 CONT	PAGE 7 of 10

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN LEFT FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (6, 5, 4, 3, 2, 1)	PLY top (# + desc) offending bottom
153			PEACH			
154	DP	5	CHAM			
155			YEL			
156			CHAM.			
157	DP	4	WT. OX			
158			CHAM.			
164			CHAM			
165	DP	4, 5	WT BROAD			
166			CHAM			
169			BLU. ST			
170	DP	4	CHAM			
171			YEL			
170			CHAM			
171	DP	4	YEL			
172			CHAM			
172			YEL			
173	DP	5	CHAM			
174			PEACH			
174			PEACH			
175	DP	4	WHT BROAD			
176			MIC GRN			
			WT BROAD			
	DP	4	ASTL GRN			
[illegible]			LT BL OX STIFF			
176			LT BL OX STIFF			
177	DP	4, 5	LT BL BROAD			
178			PEACH			
178			PEACH			
179	DP	4, 5	MIC GRN			
180			PEACH			
180			PEACH			
181	DP	4, 5, 6	LT BL STIFF OX			
182			PEACH			
181			LT BL STIFF			
182	DP	4	PEACH			
183			WENDYS			

Person Running the Test	AJA + MN	Date	7/13/95
Time Started	9:00 Am	Time Finished	9:45 Am
GENERAL BUNDLE ID	PINK/WHT (4) [illegible] RIGHT	PAGE	8 of 10

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
182	DP	5,4	PEACH			
183			WENDYS			
184			WHT OX			
183	DP	5,4	WENDYS			
184			WT OX			
185			MIL GRN			
186	DP	5	LTBL OX STIFF			
187			WENDYS			
188			WHT OX			
188	DP	4	WHT OX			
189			LT BL STIFF			
190			PINK OX			
	192	PCIES				

Person Running the Test AJA + MN						Date 3/16/95
Time Started 9:50 AM				Time Finished		
GENERAL BUNDLE ID WHT/PINK (5) RIGHT						PAGE 9 ~~6~~ of 10
	BUNDLE IN LEFT FEEDER BANK A ~~or~~ B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
7			Lt blue ox [illegible]			
8	MP	6	Mil Green			
9			White ox			
15			Peach			
16	MP	6	Lt blu bd Cl[illegible]			
17			Lt blu ox			
29			Chambray			Chambray
30	MP	6, 4	Dark blue	~~2~~ MP	2, 1	Dark Blue
31			Chambray			Chambray
44						Yellow
45	~~MP~~			MP	2	Dark blue
46						Peach
50			Chambray			Chambray
51	MP	6	Dark blue	MP	2, 1	Dark blue
52			Pink ox			Pink ox
58			Chambray			
59	MP	6, 4	Dark blue			
60			Peach			
62			White ox			
63	MP	6, 4	Dark blue			
64			Chambray			
67			Peach			Peach
68	MP	4	Dark blue	MP	3, 1	Dark blue
69			Chambray			Chambray
118			Chambray			
119	MP	4	Dark blue			
120			Wendy			
128			Wendy			
129	MP	4	Dark blue			
130			Wendy			
145						Chambray
146				MP	2	Dark blue
147						Peach
180			Wht bd			
181	DP	5	Wendy			
182			White ox			

Bundle 3 - Page 10 of 10

Person Running the Test	AJA + MN	Date	7/16/95
Time Started	9:50 AM	Time Finished	10:20 AM
GENERAL BUNDLE ID	White/Pink (5) RIGHT	PAGE	~~8~~ 10 of 10

	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
181 182 183				DP	3	Wendys White ox Lt blu ox
191 192 ~~193~~	MP	6, 4	Blue Stripe Whit brd	MP	2	Blue Stripe White brd [illegible]

TOTAL 192 PLIES ✓

OFFICIAL BUNDLE #4

Person Running the Test	AJA + MN	Date	7/16/95
Time Started	10:20 AM	Time Finished	10:45 AM
GENERAL BUNDLE ID	Blue Stripe / Yellow ox ① RIGHT	PAGE	1 of

	BUNDLE IN LEFT FEEDER BANK (A) or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK (B) or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
21			Chambray			
22	MP	6	Dark blue			
23			Lt blue ox Stiff			
31						Pink ox
32				MP	2	Dark blue
33						Lt blue ox Stiff
49			Yellow			
50	MP	4	Dark blue			
51			Lt blue ox Stiff			
112			Wendys			
113	MP	4	Dark blue			
114			Chambray			
120						White brd
121				DP	1	Chambray
122						White ox
126			Lt blue ox St			Lt blue ox St
127	MP	4	Dark blue	MP	3, 2	Dark blue
128			Blue stripe			Blue stripe

TOTAL = 129 PLIES

Person Running the Test	AJA + MN			Date	7/16/95	
Time Started	10:50 AM		Time Finished	11:15		
GENERAL BUNDLE ID	BLUE STRIPE/YELLOW OX (2)			RIGHT		PAGE 2 of
	BUNDLE IN LEFT FEEDER BANK A or (B) (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK B or (A) (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
2						BLU STR
3				MP	2,1	DRK BLU
4						LT BL OX
16						CHAM
17				MP	21	DK BL
18						WENDYS
23						YEL
24				MP	2	LT BL OX STRK
25						PINK
33						BL STRIPE
34				MP	2	DRK BL
35						WT BROAD
46						CHAM
47				MP	2	DK BLU
48						BLU STR
53			LT BL BROAD			
54	MP	4	DK BLU			
55			WT BROAD			
88			PINK			
89	DP	5	LT BL BROAD			
90			PEACH			
104			WENDY			
105	DP	5	LT BL BROAD			
106			YELLOW			
111			WHIT			
112	DP	5	WENDYS			
113			LT BL OX STRK			
115			BL ST			
116	DP	5	PEACH			
117			PINK			
127			CHAM			
128	DP	5	WHT OX			
129			BL STR			

129 PLIES

Person Running the Test: AJA + MN				Date: 7/16/95		
Time Started: 11'15 →				Time Finished: 11:55 AM		
GENERAL BUNDLE ID: BLU STR. / YEL (3) RIGHT						PAGE 3 of
	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
31						PINK
32				MP	2	DK BLU
33						LT BL OX STIFF
49			YEL			
50	MP	4	DK BL			
51			LT BL OX STIFF			
50			DK BL			
51	DP	6	LT BL OX STIFF			
52			WENDYS			
51			Lt blue ox Sti			
52	DP	6	WENDYS			
53			PINK			
61			Chambray			
62	DP	6	Yellow ox			
63			Pink ox			
114			Dark blue			
115	MP	5	Chambray			
116			Mil Green			
127			Lt blue ox Stif			Lt blu ox Stif
128	MP	4	Dark blue	MP	2	Dark blue
129			Lt blue stripe			blue Stripe

Total 129

Person Running the Test	AJA + MN	Date	7/16/95
Time Started	12:00 PM	Time Finished	12:20 PM
GENERAL BUNDLE ID	BLUE STRIPE / YELLOW (4) RIGHT	PAGE	4 of

PLY #'S	BUNDLE IN LEFT FEEDER BANK A or (B) (Circle One) — Error: TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	BUNDLE IN ~~LEFT~~ RIGHT FEEDER BANK B or (A) (Circle One) — Error: TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
2	MP	4	Blue stripe	MP	2,1	Blue Stripe
3			Dark blue			Dark blue
4			Lt blue ox			Lt blue ox
16	MP	4	Chambray	MP	2,1	Chambray
17			Dark blue			Dark Blue
18			Wendys			Wendys
33	MP	4	Blue Stripe	MP	2	Blue Stripe
34			Dark Blue			Dark Blue
35			White brdcloth			White brd cloth
46	MP	4	Chambray	MP	2	Chambray
47			Dark blue			Dark blue
48			Blue Stripe			Blue Stripe
92	DP	5	White brd			
93			Chambray			
94			White ox			
93	DP	4	Chambray			
94			White ox			
95			Wendys			
101	DP	5	Blue Stripe			
102			White broad			
103			Lt blu ox Strp			
104	DP	4	Wendys			
105			Lt blu broad			
106			Yellow ox			
111	DP	5	White ox			
112			Wendys			
113			Lt blue ox Strp			
123	DP	5	Yellow			
124			Lt blu broad			
125			Pink			
126	DP	5	Peach			
127			Chambray			
128			White ox			

Total = 129 PLIES

Person Running the Test	AJA + MN			Date	7/16/95	
Time Started	12:30			Time Finished	12:45	
GENERAL BUNDLE ID	BLUE STRIPE / YELLOW (5)			RIGHT		PAGE 5 of
	BUNDLE IN LEFT FEEDER BANK (A) or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK (B) or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
8 9 10	MP	6,4	Lt blue ox St Dark blue Chambray			
21 22 23	MP	6	Chambray Dark blue Lt blue ox St	MP	2,1	Chambray Dark blue Lt blue ox St
49 50 51	MP	6,4	Yellow Dark blue Lt blue ox St			
108 109 110	DP	5	Lt blue brd White brd Lt blue ox			
115 116 117	MP	5	White ox Lt blue brd Peach			
119 120 121	DP	5	White brd Chambray White ox			
125 126 127	MP	4	Lt blue ox St Dark blue Blue Stripe	MP	2	Lt blue ox St Dark blue Blue Stripe

Total 129 PLIES

Appendix H - Post-experimental Calibration Tests

Test 1 - Page 1 of 2

POST EXPERIMENT CALIBRATION TEST

Person Running the Test	AJA + MN				Date	7/19/95
Time Started	3:00pm			Time Finished 4:30		
GENERAL BUNDLE ID	WHITE			RIGHT		PAGE of
	BUNDLE IN LEFT FEEDER BANK (A) or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK (B) or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
PASS	#1	191 PLIES	NO	MISPICK		
PASS	#2	BUNDLES	SWITCHED			
	DP	5	350	STACK	MISALIGNMENT?	
	~~DP~~	~~5~~	~~363~~ *	STACK	MISALIGNED	
	MP	5	377	END OF	BUNDLE?	
		380	PLIES			
PASS	#3	STOPPED @	500 PLIES			
	7/21/95		RESUMED	TEST	9:00 9.45	
	DP	5	563			
PASS	#4 DPS	~~DP~~ ~~[illegible]~~	~~[illegible]~~ 164	STACK MISALIGNMENT?	9:45 - ?	
		DPS	736			
		DPS	739			

Test 1 - Page 2 of 2

Person Running the Test	AJA + MN			Date	7/21/95	
Time Started				Time Finished		
GENERAL BUNDLE ID		WHITE			RIGHT	PAGE of
	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			BUNDLE IN ~~LEFT~~ FEEDER BANK B or A (Circle One)		
	Error			Error		
PLY #'S	TYPE mispick doublepick other	PICKER # (6, 5, 4, ~~3, 2, 1~~)	PLY top (# + desc) offending bottom	TYPE mispick doublepick other	PICKER # (~~6, 5, 4~~, 3, 2, 1)	PLY top (# + desc) offending bottom
	~~PASS~~	~~#5~~				
	PASS	#4 COND				
		DPS	741			
		DPS	743	STACK	ALIGNMENT ERROR	
		DPS	744		(HOLDDOWN FINGER ~~BARELY~~	
		DPS	745		TOUCHING EDGE OF PLY	
		MPS	748	PASS ~~TEST~~	#4 ENDS @ 750 PLIES	
PASS	#5	MPS	927	FABRIC HOLD DOWN ~~D/N CLEAR~~	D/N CLEAR FINGER ~~FABRIC~~	
		MPS	936	SAME AS		
			939 END			
PASS #6			939 TO 1000	NO MISPICKS		

TEST OF PICKER INTERACTION

Person Running the Test AJA + MN					Date 7/21/95	
Time Started TEST				Time Finished		
GENERAL BUNDLE ID WHITE				RIGHT		**PAGE** of
	BUNDLE IN LEFT FEEDER BANK A or B (Circle One)			**BUNDLE IN ~~LEFT~~ FEEDER BANK** B or A (Circle One)		
	Error			Error		
PLY #'S	**TYPE** mispick doublepick other	**PICKER #** (6, 5, 4, ~~3, 2, 1~~)	**PLY** top (# + desc) offending bottom	**TYPE** mispick doublepick other	**PICKER #** (~~6, 5, 4~~, 3, 2, 1)	**PLY** top (# + desc) offending bottom
	PICKERS	5	~~[illegible]~~ [illegible] 2	TURNED	OFF	
	HOLDDOWN	FINGERS		TRAPPED	PLY	
	OTHER	PICKERS	STILL	PICKED		
	REMOVING		CENTER	HOLD DOWN	FINGERS	
		#2S FINGER HEIGHT	CONTROLS		STACK	
	REMOVING	HOLDDOWN		FINGER	#5 ONLY	
	PICKERS	3,2,1	OFF			
		500 ~~150~~ PLIES	PICKED			
		NO	MISPICKS			
	MP	#6	528			
	DP	#6	764	875	PLIES 2 MISPICKS	
				– END –		

Appendix I - AMCIA Example

(Based on Scenario 01.b From Appendix M)

Directions

The Directions worksheet is self-explanatory.

CLEMSON
CLEMSON UNIVERSITY

APPAREL MANUFACTURING CAPITAL INVESTMENT ADVISOR

Version 3.1
June, 1993

Clemson Apparel Research
Pendleton, SC 29670
803-646-8454

DIRECTIONS

Enter the INPUT in OUTLINED boxes like this	
Shaded boxes contain the calculated RESULTS (you can not enter anything in them)	
Positive and zero values are shown in BLUE	1234.6
Negative values are shown in RED	-1234.6

To analyze an investment using AMCIA:

1. Complete the "Company Data Sheet".
2. Complete the appropriate worksheets.
3. Consult the "Summary Table" for the results.

END OF DIRECTIONS

Company Data Sheet

This worksheet accounts for basic company information.

COMPANY DATA

Company name:

Project:

Number of annual working weeks: 49

Interest on the 3 month U.S. treasury bill: 6%
(or another rate available for a safe investment such as the yield of a treasury bill maturing in about 6 years)

Company tax rate: 35%

Fringe benefits as a percentage of payroll:

Direct Labor	23%
Indirect Labor	25%

Estimated average unit sale price of the product if you were to continue with current technology (dollars):

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
10.00	10.25	10.50	10.75	11.00	11.25

Estimated number of units to be produced if you were to continue with current technology:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
932262	932262	932262	932262	932262	932262

Estimated sales of the products affected by this decision if you were to continue with current technology (dollars):

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
9322620	9555686	9788751	10021817	10254882	10487948

END OF 'COMPANY DATA SHEET'

Number of Annual Working Weeks

There are 52 weeks in a year. In a typical U.S. manufacturing facility each employee gets two weeks of vacation a year. An additional week is taken up by miscellaneous holidays such as Thanksgiving, Christmas, New Years, Easter, and the like. For the AMCIA analysis the number of annual working weeks will be listed as 49.

Interest on a 3 Month U.S. Treasury Bill

Unfortunately, differences exist between the values AMCIA accepts and the values AMCIA displays. For example, when a value of 5.6% was entered into AMCIA's "Interest on the 3 month U.S. treasury bill" cell, the cell displayed the input value as 6%. AMCIA used 5.6% to perform the calculations, however. To avoid confusion, all of the values put into AMCIA were made to match the values displayed by AMCIA, even if rounding of

input values was necessary. Hence, although treasury bills had a yield of 5.6% at the time this worksheet was done, the value entered into AMCIA was the value displayed, 6%. Hopefully future versions of AMCIA will follow the WYSIWYG (What You See Is What You Get) software doctrine so that such confusion is avoided.

Company Tax Rate

The company tax rate for apparel manufacturers is 35%.

Fringe Benefits as a Percentage of Payroll

According to John Mahoney, CAR's Assistant Site Director, direct labor fringe benefits are typically 23% of payroll while indirect labor fringe benefits are typically 25% of payroll.

Estimated Average Unit Sale Price

Again, according to John Mahoney men's single-needle, long-sleeve, dress, shirts are sold to retailers for $10.00 a piece. John estimated that the cost would rise $0.25 per year over the six year depreciation life of the Clupickers.

Estimated Number of Units to be Produced Using Current Technology

Jet Sew 5001 Automatic Front Loaders have been purchased by a number of shirt manufacturers.[I.1] According to Thomas Mitchell and Sonny Sweezy, of the Southeast Manufacturing Technology Center (SMTC), these plants can be classified as medium to large manufacturing facilities. According to Sonny, a typical medium sized shirt manufacturer has between 100 and 200 sewing operators. Assuming a plant has 100 operators and each operator works eight hours, and assuming a single shirt takes 15 minutes to make, this translates to a production rate of 3,200 shirts per day.

From calculations described in the Direct Labor Worksheet (Equation D.L. 26), the maximum number of plies that can be processed by six Original Clupickers operating at 99.50% efficiency is 3,805 units per work day.

Note: Using the programs listed in Appendix J the actual value for Equation D.L. 26 is 3,805.15129359. To avoid accumulated round-off errors, the programs were written, and the associated outputs are presented in ***bold italics***.

As Clupicker efficiency varies so does the maximum daily production rate. Sonny's production estimate is based on a rough production model, while the Direct Labor Worksheet estimates are based on a more detailed production model. Since the purpose of the AMCIA worksheet is to develop a detailed production model, the number of units produced in the Company Data Sheet shall be based on the Direct Labor Worksheet calculations.

There is one minor modification required, however. The Direct Labor Worksheet calculated production on a daily basis. The Company Data Sheet requires data on a yearly basis. The Direct Labor Worksheet Equation D.L. 26 states:

$$\text{Production}_{\text{Actual}} = \frac{3{,}805 \text{ units}}{\text{work day}} \tag{D.L. 26}$$

This can be converted to an annual production value using:

$$\text{Production}_{\text{Annual}} = \frac{\text{units}}{\text{work day}} \times \frac{5 \text{ days}}{\text{week}} \times \frac{49 \text{ weeks}}{\text{year}} \tag{C.D.S. 1}$$

Substituting Equation D.L. 26 into Equation C.D.S. 1 yields:

$$\text{Production}_{\text{Annual}} = \frac{\text{units}}{\text{work day}} \times \frac{5 \text{ days}}{\text{week}} \times \frac{49 \text{ weeks}}{\text{year}} \tag{C.D.S. 1}$$

$$= \frac{3{,}805 \text{ units}}{\text{work day}} \times \frac{5 \text{ days}}{\text{week}} \times \frac{49 \text{ weeks}}{\text{year}}$$

$$= \boldsymbol{\frac{932{,}262 \textit{ units}}{\textit{year}}} \tag{\textit{C.D.S. 2}}$$

Although carrying out the above calculation actually yields:

$$\text{Production}_{\text{Annual}} = \frac{932{,}225 \text{ units}}{\text{year}} \tag{C.D.S. 3}$$

The value (C.D.S. 3) is based on the rounded value 3,805 instead of 3805.15129359 (see the note on page I - 3).

Investment, Installation, and Depreciation

The values entered in this worksheet are based on Jet Sew's bill to CAR for the installation of three Modified Clupickers.

INVESTMENT, INSTALLATION AND DEPRECIATION

- Depreciation source: IRS 1988; MACRS after '86 (secs 167-168, 15,686-y).
- Assets assumed to be acquired in year 0, with 5 year recovery period and half year convention.

Investment for the project (a negative number, in dollars):

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
-12000						

Original value of new equipment: 12000

Salvage value of new equipment:

Retraining expenses (negative number): -112

Installation expenses (negative number, in dollars):
(Include labor, machinery, consultation fees, transportation)

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
-356						

Amount to be depreciated: 12356

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Depreciation rates:		0.2	0.32	0.192	0.1152	0.1152	0.0576
Depreciation expenses:		2471	3954	2372	1423	1423	712
Depreciation tax savings:		865	1384	830	498	498	249

Present value: 3687

Investment cash flows:

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
-12000						

Present value: -12000

Installation, retraining cash flows:

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
-468						

Present value: -468

END OF 'INVESTMENT, INSTALLATION AND DEPRECIATION' WORKSHEET

Investment for the Project

The plant being modeled produced 3,805 shirts per day (see the Direct Labor Worksheet Equation D.L. 26). One Jet Sew Hemmer can process a maximum of 4,500 plies per day (see Direct Labor Worksheet, *S.A.M.*). The Jet Sew Hemmer is fed parts by the Jet Sew Loader which is equipped with six (6) Clupickers. So, six Clupickers were needed.

The cost of each Clupicker was $2000. This being the case, the cost of investing in Clupicker technology can be expressed as:

$$\text{Cost of Investing}_{\text{Clupickers}} = \text{Number}_{\text{Clupickers}} \times \frac{\$2000}{\text{Clupicker}} \qquad \text{(I.I.D. 1)}$$

$$= 6 \times \$2000$$

$$= \$12{,}000 \qquad \text{(I.I.D. 2)}$$

Since the investment takes place in one shot, only the Year 0 field is filled.

Original Value of New Equipment
This value will be the same as the initial cost of investing (i.e., Equation I.I.D. 2).

Salvage Value of New Equipment
This analysis assumes that at the end of six years the Clupickers have no salvage value.

Retraining Expenses
Since both the operators and mechanics must be trained to use and service the new equipment, and since both earn the same hourly wages (this was one of the initial assumptions), the following equation can be used to determine the retraining expenses:

$$\text{Expenses}_{\text{Retraining}} = \text{Hours}_{\text{Training}} \times \frac{\$}{\text{hour}} \qquad \text{(I.I.D. 3)}$$

where:

$$\text{Hours}_{\text{Training}} = [(\text{Hours}_{\text{Mechanic}} \times 2.5 \text{ days}) + (\text{Hours}_{\text{Operator}} \times 1 \text{ day})] \times \frac{8}{\text{day}}$$

$$= 28 \text{ hours} \qquad \text{(I.I.D. 4)}$$

and:

$$\frac{\$}{\text{hour}} = \frac{\$4.00}{\text{hour}} \qquad \text{(I.I.D. 5)}$$

Plugging I.I.D. 4 and I.I.D. 5 into I.I.D. 3 yields:

$$\text{Expenses}_{\text{Retraining}} = \text{Hours}_{\text{Training}} \text{ x } \frac{\$}{\text{hour}} \qquad \text{(I.I.D. 3)}$$

$$= 28 \text{ hours x } \$4.00/\text{hour}$$

$$= \$112 \qquad \text{(I.I.D. 6)}$$

Installation Expenses

The cost of installing three (3) Clupickers was $356. Because of the way the Jet Sew Loader is designed, the effort of installing six Clupickers does not seem much more that the effort required to install three Clupickers. The cost of installing the Clupicker technology can therefore be expressed as:

$$\text{Cost of Installing}_{\text{Clupicker}} = \text{Number}_{\text{Clupickers}} \text{ x } \frac{\$356}{6 \text{ Clupickers}} \qquad \text{(I.I.D. 7)}$$

$$= 6 \text{ x } \frac{\$356}{6 \text{ Clupickers}}$$

$$= \$356 \qquad \text{(I.I.D. 8)}$$

Since the installation only takes place once, the Year 0 field is the only one filled.

Old Equipment Sale

No information was available concerning the sale of used Clupickers, and so this worksheet was left blank.

OLD EQUIPMENT SALE

Book value of the old equipment:	
Market value of the old equipment:	
You'll pay a tax of:	
Before-tax cash flow:	

Summary of Old Equipment Sale

After-tax cash flow (Year 0):	
Present value:	

END OF 'OLD EQUIPMENT SALE' WORKSHEET

Direct Labor

DIRECT LABOR

	Present	Projected
S.A.M. (min/unit):	0.1067	0.1067
Base rate ($/min):	0.0667	0.0667
Direct labor efficiency (%):	84.5589	92.4978
Earned pay ($/unit):	0.0084	0.0077
Excess costs (% earned pay per unit): (Overtime, make-up, wait for work, machine delay, job transfers)	0.0000	0.0000
Total annual workers' comp. as a percentage of direct labor, not including fringe benefits.	0.00	0.00
Cost ($/unit):	0.0084	0.0077

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Implied change in annual production capacity (units):	74011	74011	74011	74011	74011	74011
Amount of the change in production capacity you wish to exploit:	74011	74011	74011	74011	74011	74011

Summary of Direct Labor

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Direct labor savings (in dollars):	128	128	128	128	128	128
Revenues due to exploited change in production capacity:	740110	758613	777116	795618	814121	832624
After-tax equivalent of the above two cash flows:	481155	493181	505208	517235	529262	541289

Confidence in this estimate (1-100): 90

Present value: 2253431

END OF 'DIRECT LABOR' WORKSHEET

S.A.M., Present and Projected

The S.A.M. cell is used to enter the Standard Allowed Minutes (min./unit) for the particular machine whose purchase is being considered. In calculating the S.A.M.'s for the Jet Sew Feeder, one must remember that the throughput rate of the Feeder is not limited by the throughput rate of the Clupickers (which are rated at 20 picks per minute[I.2]). The Feeder's throughput is limited by the Jet Sew Model 2621 Centerplaite/Sleeve Hemmer which is attached to the Feeder.

According to Charlotte Pierce, who is responsible for CAR's Demo Floor operations, the Jet Sew Automatic Hemmer, sewing 12 stitches per inch, and running continuously and flawlessly, can process 4,500 medium men's right fronts in eight hours. This means it takes 480 minutes to process

enough fronts to complete 4,500 shirts. 480 minutes per 4,500 shirts translates to 0.1067 minutes per unit (a shirt) or 0.1067 S.A.M.'s. This S.A.M. value is the same for the Original Clupickers and the Modified Clupickers. The reason for this is explained below.

The S.A.M. value above is calculated from Hemmer performance data but is applied to the Clupickers even though the Clupickers can pick 20 times per minute (S.A.M. = 0.0500). The reason for this is that the Clupickers are subcomponents of the Feeder and the Feeder is linked to the Hemmer. The Clupickers only pick when the Hemmer asks the Feeder for more parts. This means that the S.A.M. value for the Clupickers is limited to the S.A.M. value of the Hemmer. (This statement meshes with questionnaire responses listed in the report Enhance the Commercial Acceptance of an Automatic Ply Separation & Feeding System for Apparel Fabrics by Robert Keith Daniel.)[I.3]

This interrelationship between the Hemmer, Feeder, and Clupickers shows how misleading it is to assume that improved Clupicker performance will automatically translate into improved production rates. In this example it is obvious that if the Clupickers are performing optimally, they have little or no impact on the Hemmer's throughput performance. Only when the Clupicker performance drops below the Hemmer performance will the Clupickers have any impact on production. If one considers the entire shirt manufacturing process it is easy to see how any benefits derived from improved Clupicker performance can be completely negated by other processes involved in shirt manufacturing.

Base Rate, Present and Projected

The base rate is hourly worker wages expressed in minutes. For example, if an operator running the Jet Sew Feeder is paid $4.00 an hour, this translates to a base rate of $4.00 divided by 60 minutes or 0.0667 $/min..

Direct Labor Efficiency, Present

Since direct labor (an operator) is necessary for loading and supervising the operation of the Jet Sew Hemmer, direct labor efficiency is closely linked to Hemmer performance and hence Clupicker performance. If the Clupickers do not mispick, little direct labor is required to oversee the Hemmer's operation, and the direct labor can be redirected to another operation (once the Hemmer is loaded and running). If the Clupickers mispick occasionally more of an operators time must be spent correcting the mispick conditions. If the Clupickers mispick even more, both direct labor (an operator) and indirect labor (a mechanic) become involved with the Hemmer's operation and labor efficiencies fall even further. If the Clupickers do not work at all, an operator is assigned the full-time job of loading the Hemmer and no direct labor savings are realized at all.

Mathematically the direct labor efficiency is defined by the following equation:

$$\text{Efficiency}_{\text{Direct Labor}} \equiv \frac{\text{Production}_{\text{Actual}}}{\text{Production}_{\text{Maximum}}} \qquad \text{(D.L. 1)}$$

Maximum production is easy to calculate. It is based on the same information used to complete the S.A.M. cells (see above).

$$\text{Production}_{\text{Maximum}} = \frac{\text{4,500 units}}{\text{8 hrs (one work day)}} \qquad \text{(D.L. 2)}$$

Now that a value for Production $_{\text{Maximum}}$ has been calculated, a value for Production $_{\text{Actual}}$ needs calculating. Production $_{\text{Actual}}$ is defined by the following equation:

$$\text{Production}_{\text{Actual}} = \text{Throughput}_{\text{Actual}} \times \text{Time}_{\text{Available}} \qquad \text{(D.L. 3)}$$

By definition:

$$\text{Throughput}_{\text{Actual}} \equiv \frac{\text{Plies}_{\text{Processed}}}{\text{Time}_{\text{Spent Processing}}} \qquad \text{(D.L. 4)}$$

Or, by simply changing variable names,

$$\text{Throughput}_{\text{Actual}} \equiv \frac{\text{Ply}_{\text{Loaded}}}{\text{Time}_{\text{Process}}} \qquad \text{(D.L. 5)}$$

(Variable names were changed to avoid confusion in later calculations.)

Looking at Figure 3-3 it is apparent that during a typical day of processing, time is spent loading, picking, mispicking, fixing mispicks and repicking the fabric plies. To determine how much time is spent processing the plies

that have been loaded requires evaluating how much time has been spent at each step in processing and how many plies have been involved in each step. Mathematically this can be expressed as:

$$\frac{\text{Time}_{\text{Process}}}{\text{Ply}_{\text{Loaded}}} = \frac{\text{Time}_{\text{Load}}}{\text{Ply}_{\text{Nominal}}} + \frac{\text{Time}_{\text{Pick}}}{\text{Ply}_{\%}} + \frac{\text{Time}_{\text{Mispick}}}{\text{Ply}_{(1-\%)}} + \frac{\text{Time}_{\text{Fix}}}{\text{Ply}_{(1-\%)}} + \frac{\text{Time}_{\text{Repick}}}{\text{Ply}_{(1-\%)}}$$

(D.L. 6)

Each part of Equation D.L. 6 will be discussed in detail.

The first step in solving Equation D.L. 6 involves calculating the amount of time required to load the Jet Sew Loader on a time per ply basis. To start, assume that in a typical shirt manufacturing plant spreads are made 200 plies high. This means that bundles of cut parts contain 200 plies. Also assume that because it is difficult to handle 200 ply bundles without disturbing the ply alignment, the bundles are loaded one at a time into the Jet Sew Loader. (This is certainly in agreement with the test team's experiences with large bundles.) Finally, assume that the entire process of loading a single bundle and making adjustments to the bundle to ensure proper feeding takes 30 seconds. (Again, this is in agreement with the test team's experiences with large bundles.)

Using the above information it is possible to calculate the amount of time required to load a single ply:

$$\frac{\text{Time}_{\text{Load}}}{\text{Ply}_{\text{Nominal}}} = \frac{30 \text{ seconds}}{200 \text{ plies}} = \frac{0.1500 \text{ sec}}{\text{ply}} \qquad \text{(D.L. 7)}$$

The next step in solving Equation D.L. 6 involves calculating the amount of time spent by the Original Clupicker Group correctly picking plies on a per ply basis.

$$\frac{\text{Time}_{\text{Pick}}}{\text{Ply}_{\%}} = \frac{\text{Time}_{\text{Day}}}{\text{Ply}_{\text{Maximum}}} \times \frac{\text{Ply}_{\text{Pick}}}{\text{Ply}_{\text{Available}}} \qquad \text{(D.L. 8)}$$

where:

$$\frac{\text{Time}_{\text{Day}}}{\text{Ply}_{\text{Maximum}}} = \frac{\text{8 hours}}{\text{4,500 plies}} = \frac{\text{28,800 seconds}}{\text{4,500 plies}} = \frac{\text{6.4000 sec}}{\text{ply}} \qquad \text{(D.L.9)}$$

and:

$$\frac{\text{Ply}_{\text{Pick}}}{\text{Ply}_{\text{Available}}} = (\text{Reliability}_{\text{Original Clupicker}})^{\text{6 Clupickers / Group}}$$

$$= (0.9950)^6$$

$$= 0.970373$$

$$= 97.0373\% \qquad \text{(D.L. 10)}$$

Plugging values into Equation D.L. 8 yields:

$$\frac{\text{Time}_{\text{Pick}}}{\text{Ply}_{\%}} = \frac{\text{6.4000 sec}}{\text{ply}} \times 97.0373\% = \frac{\text{6.2104 sec}}{\text{ply}} \qquad \text{(D.L. 11)}$$

The next step involves calculating the amount of time wasted by the Original Clupicker Group in mispicking plies on a per ply basis.

$$\frac{\text{Time}_{\text{Mispick}}}{\text{Ply}_{(1-\%)}} = \frac{\text{Time}_{\text{Day}}}{\text{Ply}_{\text{Maximum}}} \times \frac{\text{Ply}_{\text{Mispick}}}{\text{Ply}_{\text{Available}}} \qquad \text{(D.L. 12)}$$

where the first variable is defined by Equation D.L. 9 and the second

variable is defined as:

$$\frac{\text{Ply}_{\text{Mispick}}}{\text{Ply}_{\text{Available}}} = 1 - (\text{Reliability}_{\text{Original Clupicker}})^{6\ \text{Clupickers / Group}}$$

$$= 1 - 0.970373$$

$$= 0.029637$$

$$= 2.9627\% \qquad \text{(D.L. 13)}$$

were 0.9704 came from Equation D.L. 10.

Plugging the values from Equations D.L. 9 and D.L. 13 into Equation D.L. 12 yields:

$$\frac{\text{Time}_{\text{Mispick}}}{\text{Ply}_{(1-\%)}} = \frac{6.4000\ \text{sec}}{\text{ply}} \times 2.9627\% = \frac{0.1896\ \text{sec}}{\text{ply}} \qquad \text{(D.L. 14)}$$

The next step in solving Equation D.L. 6 involves calculating the amount of time spent correcting mispick errors. The time is expressed as seconds per mispicked ply.

$$\frac{\text{Time}_{\text{Fix}}}{\text{Ply}_{(1-\%)}} = \frac{\text{Ply}_{\text{Mispick}}}{\text{Ply}_{\text{Available}}} \times \frac{\text{Time}_{\text{Fix}}}{\text{Mispick}} \qquad \text{(D.L. 15)}$$

The first variable is described by Equation D.L. 13. The second variable requires additional clarification.

$$\frac{\text{Time}_{\text{Fix}}}{\text{Mispick}} = \frac{\text{Time}_{\text{Acknowledge}}}{\text{Mispick}} + \frac{\text{Time}_{\text{Diagnose}}}{\text{Mispick}} + \frac{\text{Time}_{\text{Correct}}}{\text{Mispick}} \qquad \text{(D.L. 16)}$$

Assume that it takes ten (10) seconds to acknowledge a mispick. This is not an unreasonable assumption since the Jet Sew Loader does not have any

way of alerting an operator that a mispick condition has occurred beyond stopping the Jet Sew Hemmer. In a busy manufacturing plant, an operator cannot hear the Hemmer stopping. If the operator is busy repairing damaged plies or is preparing bundles for loading, it is also unlikely that the operator will be see Hemmer stop. The only way that mispicks can be corrected immediately is if the operator is constantly monitoring the Loaders performance and nothing else. Unless the operator is monitoring several Jet Sew Loaders at once, constant monitoring of a single Loader is highly improbable.

Also assume that once a mispick is acknowledged that it takes a skilled operator five (5) seconds to diagnose what caused the mispick and how to set about correcting the mispick condition. And finally, assume that it takes the skilled operator five (5) seconds to actually correct the mispick.

Using these assumptions,

$$\frac{\text{Time}_{\text{Fix}}}{\text{Mispick}} = \frac{10 \text{ sec}}{\text{mispick}} + \frac{5 \text{ sec}}{\text{mispick}} + \frac{5 \text{ sec}}{\text{mispick}} = \frac{20 \text{ sec}}{\text{mispick}}$$

(D.L. 17)

Plugging D.L. 13 and D.L. 17 into D.L. 15 yields

$$\frac{\text{Time}_{\text{Fix}}}{\text{Ply}_{(1-\%)}} = 2.9627\% \text{ x } \frac{20 \text{ sec}}{\text{mispick}} \text{ x} \left(\frac{1 \text{ mispick}}{1 \text{ ply}} \right)_{\text{Conversion Factor}} = \frac{0.5925 \text{ sec}}{\text{ply}}$$

(D.L. 18)

The final piece of information needed to complete Equation D.L. 6 is the amount of time required to repick mispicked plies on a time-per-ply basis. If the Clupickers were picking at 100% efficiency, the time required to repick mispicked plies would be the same as the time required to mispick the plies in the first place. This is because all plies (picked, mispicked, or repicked) get picked at the same rate. Since the Clupickers do not operate at 100% efficiency, however, some of the repicked plies would also be mispicked. This means that some of the plies would have to be re-repicked. Some mispicks would occur to these plies, and the process would continue ad-infinitum until the last ply was picked. To avoid confusion about re-

repicked plies and for the sake of simplicity in an already complex area, the test team decided to make the following approximation:

$$\frac{\text{Time}_{\text{Repick}}}{\text{Ply}_{(1-\%)}} \approx \frac{\text{Time}_{\text{Mispick}}}{\text{Ply}_{(1-\%)}} \tag{D.L. 19}$$

$$= \frac{0.1896 \text{ sec}}{\text{ply}} \tag{D.L. 14}$$

Now that all of the unknowns associated with the right-hand-side of Equation D.L. 6 have been found, the equation can be solved. Using D.L. 7, 11, 14, 18, and 19:

$$\frac{\text{Time}_{\text{Process}}}{\text{Ply}_{\text{Loaded}}} = \frac{0.1500 \text{ sec}}{\text{ply}} + \frac{6.2104 \text{ sec}}{\text{ply}} + \frac{0.1896 \text{ sec}}{\text{ply}} + \frac{0.5925 \text{ sec}}{\text{ply}} + \frac{0.1896 \text{ sec}}{\text{ply}}$$

$$= \frac{7.3322 \text{ sec}}{\text{ply}} \tag{D.L. 20}$$

Now, recognizing that:

$$\text{Throughput}_{\text{Actual}} \equiv \frac{\text{Ply}_{\text{Loaded}}}{\text{Time}_{\text{Process}}} = \left(\frac{\text{Time}_{\text{Process}}}{\text{Ply}_{\text{Loaded}}} \right)^{-1} \tag{D.L. 5}$$

We can calculate the actual throughput to be,

$$\text{Throughput}_{\text{Actual}} = \frac{\text{ply}}{7.3322 \text{ sec}} = \frac{0.1364 \text{ plies}}{\text{second}} \tag{D.L. 21}$$

Equation D.L. 3 stated:

$$\text{Production}_{\text{Actual}} = \text{Throughput}_{\text{Actual}} \times \text{Time}_{\text{Available}} \qquad \text{(D.L. 3)}$$

The actual throughput was calculated in Equation D.L. 21. The only piece of information missing is the $\text{Time}_{\text{Available}}$. Figure 3-3 shows that in a day, the time available for running the Hemmer can be defined as:

$$\text{Time}_{\text{Available}} = \text{Time}_{\text{Day}} - \text{Time}_{\text{Setup}} \qquad \text{(D.L. 22)}$$

Where,

$$\text{Time}_{\text{Day}} = 8 \text{ hours} = 28{,}800 \text{ seconds} \qquad \text{(D.L. 23)}$$

and,

$$\text{Time}_{\text{Setup}} = \text{Hours}_{\text{Setup}} = 0.25 \text{ hours} = 900 \text{ seconds} \qquad \text{(I.L. 10)}$$

Putting Equations D.L. 23 and I.D. 10 into Equation D.L. 22 yields,

$$\begin{aligned} \text{Time}_{\text{Available}} &= 28{,}800 \text{ seconds} - 900 \text{ seconds} \\ &= 27{,}900 \text{ seconds} \qquad \text{(D.L. 24)} \end{aligned}$$

Now substituting D.L. 21 and D.L. 22 into Equation D.L. 3 yields

$$\begin{aligned} \text{Production}_{\text{Actual}} &= \frac{0.1364 \text{ plies}}{\text{second}} \times 27{,}900 \text{ seconds} \\ &= 3{,}805 \text{ plies} \qquad \text{(D.L. 25)} \end{aligned}$$

Remember that one ply picked by the Jet Sew Loader is equivalent to one unit processed by the Jet Sew Hemmer. Also remember, the actual

production rate was based on the amount of time available to use the Jet Sew Hemmer in the course of a work day, so Equation D.L. 23 can be restated as:

$$\text{Production}_{\text{Actual}} = \frac{3{,}805 \text{ units}}{\text{work day}} \qquad \text{(D.L. 26)}$$

Using D.L. 2 and D.L. 26 it is now possible to solve Equation D.L. 1.

$$\text{Efficiency}_{\text{Direct Labor}} \equiv \frac{\text{Production}_{\text{Actual}}}{\text{Production}_{\text{Maximum}}} \qquad \text{(D.L. 1)}$$

$$= \frac{\dfrac{3{,}805 \text{ units}}{\text{work day}} \quad \text{(D.L. 26)}}{\dfrac{4{,}500 \text{ units}}{\text{work day}} \quad \text{(D.L. 2)}}$$

$$= 0.8455$$

$$= \boldsymbol{\mathit{84.5589\%*}} \qquad \textbf{\textit{(D.L. 27)}}$$

* See note on page I - 3.

We have now calculated the Direct Labor Efficiency for the present working condition. Now we must calculate the Direct Labor Efficiency for the projected working condition.

Direct Labor Efficiency, Projected

All of the main calculations used to determine the Present Direct Labor Efficiency can also be used to determine the Projected Direct Labor Efficiency. Two major differences between the present and projected

calculations are a result Equations D.L. 10 and D.L. 13.

$$\frac{\text{Ply}_{\text{Pick}}}{\text{Ply}_{\text{Available}}} = (\text{Reliability}_{\text{Original Clupicker}})^{6\ \text{Clupickers / Group}} \qquad \text{(D.L. 10)}$$

$$= (0.9990)^{6}$$

$$= 0.994015$$

$$= 99.4015\% \qquad \text{(D.L. 28)}$$

And:

$$\frac{\text{Ply}_{\text{Mispick}}}{\text{Ply}_{\text{Available}}} = 1 - (\text{Reliability}_{\text{Original Clupicker}})^{6\ \text{Clupickers / Group}} \qquad \text{(D.L. 13)}$$

$$= 1 - 0.994015$$

$$= 0.005985$$

$$= 0.5985\% \qquad \text{(D.L. 29)}$$

The only other change of any consequence requires its own discussion.

The amount of time required to setup the Original Clupickers was derived from Equation I.L. 10 located on the Indirect Labor Worksheet.

$$\text{Hours}_{\text{Setup}} = 0.25 \text{ hours} \qquad \text{(I.L. 10)}$$

To calculate the amount of time required to setup the Modified Clupickers an assumption had to be made.

It was assumed that as Clupicker performance goes up the amount of setup time required goes down. In other words, Clupicker performance time is inversely proportional to Clupicker setup time because as one goes down the other goes up. Since no direct measurements were available comparing setup times of the Original Clupickers against setup times of the Modified Clupickers, the test team made the following approximation:

$$\text{Setup Hours}_{\text{Modified}} = \text{Setup Hours}_{\text{Original}} \times \left(\frac{\text{Performance}_{\text{Modified}}}{\text{Performance}_{\text{Original}}} \right)^{-1}$$

(I.L. 13)

Using simple substitution:

$$\text{Setup Hours}_{\text{Original}} = \text{Hours}_{\text{Setup, Original}} \qquad \text{(D.L. 30)}$$

$$= 0.25 \text{ hours} \qquad \text{(I.L. 10)}$$

Again using substitution:

$$\text{Performance}_{\text{Modified}} = \frac{\text{Ply}_{\text{Pick}}}{\text{Ply}_{\text{Available}}} \qquad \text{(I.L. 15)}$$

$$= 99.4015\% \qquad \text{(D.L. 29)}$$

And once again using substitution:

$$\text{Performance}_{\text{Original}} = \frac{\text{Ply}_{\text{Pick}}}{\text{Ply}_{\text{Available}}} \qquad \text{(I.L. 16)}$$

$$= 97.0373\% \qquad \text{(D.L. 10)}$$

Now, plugging values from Equations I.L. 10, D.L. 28 and D.L. 10 into Equation I.L. 13 yields:

$$\text{Setup Hours}_{\text{Modified}} = 0.2500 \text{ hours} \times \left(\frac{99.40\%}{97.04\%} \right)^{-1}$$

$$= 0.244053794 \text{ hours}$$

$$= 879 \text{ seconds} \qquad \text{(D.L. 31)}$$

Using the values D.L. 28 and D.L. 29 and D.L. 31 it is left to the reader to verify the values calculated and identified in the summary table below.

Table D.L.-1: Calculation Summary Table				
	Present (Original Clupickers)		Present (Modified Clupickers)	
Base Equation	Output Identification	Output Value	Output Identification	Output Value
D.L. 1	See D.L. 27		See D.L. 40	
D.L. 2	D.L. 2	4,500 units/ work day	No Change	
D.L. 3	See D.L. 26		See D.L. 39	
D.L. 4	See D.L. 21			
D.L. 5	See D.L. 21		See D.L. 36	
D.L. 6	See D.L. 20		See D.L. 35	
D.L. 7	D.L. 7	0.1500 sec/ply	No Change	
D.L. 8	See D.L. 11		See D.L. 32	
D.L. 9	D.L. 9	6.4000 sec/ply	No Change	
D.L. 10	D.L. 10	97.0373%	D.L. 28	99.4015%
D.L. 11	D.L. 11	6.2104 sec/ply	D.L. 32	6.3617 sec/ply
D.L. 12	See D.L. 14		See D.L. 33	
D.L. 13	D.L. 13	2.9627%	D.L. 29	0.5985%
D.L. 14	D.L. 14	0.1896 sec/ply	D.L. 33	0.03830 sec/ply
D.L. 15	See D.L. 18		See D.L. 34	
D.L. 16	See D.L. 17		No Change	
D.L. 17	D.L. 17	20 sec/mispick	No Change	
D.L. 18	D.L. 18	0.5925 sec/ply	D.L. 34	0.1197 sec/ply
D.L. 19	See D.L. 14		See D.L. 33	
D.L. 20	D.L. 20	7.3322 sec/ply	D.L. 35	6.7080 sec/ply
D.L. 21	D.L. 21	0.1364 plies/sec	D.L. 36	0.1491 plies/sec
D.L. 22	See D.L. 24		No Change	
D.L. 23	D.L. 23	28,800 sec	No Change	
None	**I.L. 10**	900 sec	D.L. 31	879 sec
D.L. 24	D.L. 24	27,900 sec	D.L. 37	27,921 sec
D.L. 25	D.L. 25	3,805 plies	D.L. 38	4,163 plies
D.L. 26	D.L. 26	3,805 units/ work day	D.L. 39	4,163 units/ work day
D.L. 27	***D.L. 27***	***84.5589%****	***D.L. 40***	***92.4978%****
* See note on page I - 3.				

What all this means is that based on Dr. Tim Clapp's Clupicker performance ratings of 99.5+% and 99.9% for the Original and Modified Clupickers respectively, an operator working with a Jet Sew Feeder

equipped with six Clupickers produces shirt sleeves at an efficiency of 84.5589% if Original Clupickers are used and 92.4978% if Modified Clupickers are used.

Excess Costs

According to the AMCIA manual, excess costs are based on production related excesses. These excesses include overtime, make up, repairs, waiting for work, machine delay, and/or job transfers. The excesses associated with repairs and machine delay were partially accounted for under the Direct Labor Efficiency heading. Additional costs associated with repairs are discussed in the Quality Related Costs Worksheet. Additional costs associated with machine delays are accounted for in the Indirect Labor Worksheet. All other excess costs were difficult to generalize and so the Excess Cost cells were left blank.

Annual Workers /Compensation

These cells were left blank to avoid complicating the general AMCIA model.

Change in Annual Production Capacity Cells

All improvements brought about by investing in the Modified Clupicker technology were taken advantage of.

Confidence Estimate Cell

Based on a general feeling that the information provided was reasonably accurate, an arbitrary confidence value of 90 (out of a possible 100) was assigned to the Direct Labor worksheet.

Indirect Labor

The Indirect Labor worksheet helps estimate cash flows associated with the need for supervisors, inspectors, mechanics, and material handlers.

INDIRECT LABOR

	Present	Projected
Indirect labor pay rate ($/hour):	4.00	4.00
Overtime costs as a percentage of the indirect labor pay rate:		
Indirect labor costs ($/hour):	4.000	4.000
Annual indirect labor regular hours:	64	62

Summary of Indirect Labor

After-tax cash flows:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
7	7	7	7	7	7

Confidence in this estimate (1-100): 90

Present value: 29

END OF 'INDIRECT LABOR' WORKSHEET

Indirect Labor Pay Rate, Present and Projected

In this example the indirect labor pay rate was four dollars an hour ($4.00/hr).

Overtime Costs, Present and Projected

This example, and all AMCIA analysis performed for the Clupicker Project, assumes no overtime takes place. Although quotas are frequently employed in apparel manufacturing plants, all analyses done for the Clupicker project are based on maximum daily Hemmer throughput calculated using the Direct Labor Worksheet, not on flat work quotas.

Annual Indirect Labor Regular Hours , Present

CAR's experience suggests that the largest Clupicker related indirect labor costs come from the need to have mechanics adjust the Clupickers when fabric changes occur. According to Bob Bennett, CAR's head mechanic, adjusting the Original Clupickers is relatively straight forward and is only required when major fabric changes take place. According to Bob, the difficulty lies in determining what affect the Clupicker adjustments have had on the Clupicker performance levels. In most cases, the influence of adjustments is not recognized unless the Clupicker performance

dramatically changes. CAR suspects that the reason Clupickers are hard to adjust is not because of the Clupickers' design, but because the effects of Clupicker adjustments are masked by other conditions that have a greater influence on Clupicker performance.

As explained in the "Pre-experimental Setup" section, the test team had a very difficult time setting up and adjusting the Clupickers. This was not because the Clupickers were hard to adjust. The difficulty was in measuring the affect of the adjustments. Adjustment affects were frequently masked by bundle affects such as fused or frayed ply edges and misaligned plies.

As described in the "Pre-experimental Setup" section under the subheading "Bundle Reuse Not A Simple Process", the need for consistent bundles was a prerequisite to troubleshooting the Clupickers. CAR went so far as to cut special fabric using a special cutting tool to ensure that the bundle edges were not fused, were thread free, and were perfectly aligned. By eliminating bundle errors, CAR was able to directly relate Clupicker adjustments to Clupicker errors.

The single most time consuming step in the Clupicker setup process was the development of a method to provide diagnostic bundles for use in the setup process. Once CAR had located an adequate supply of material, representative of the material to be picked, and CAR had developed a means of minimizing bundle errors (the Bologna Slicer), setup of the Clupickers was simple.

Using the test team's setup experiences, along with Bob Bennett's comments, an estimate of the annual indirect labor regular hours (associated with the Original Clupickers) was made. The estimate was based on the following equation:

$$\text{Annual Hours} = \text{Annual Hours}_{\text{Developing Setup}} + \text{Annual Hours}_{\text{Setup}} \qquad \text{(I.L. 1)}$$

The first step in solving Equation I.L. 1 involves developing an expression for the number of hours spent each year developing a setup procedure. Since the development of a setup procedure would only occur once, and since the AMCIA analysis is over the six year depreciation life of the Clupickers, the time spent developing the setup procedure had to be divided over the depreciation life of the Clupickers. A simplified way of expressing

this (not taking into account the time value of money) is as follows:

$$\text{Annual Hours}_{\text{Developing Setup}} = \frac{\text{Hours}_{\text{Developing Setup}}}{6 \text{ years}} \quad \text{(I.L. 2)}$$

where,

$$\text{Hours}_{\text{Developing Setup}} = \text{Hours}_{\text{Making Bologna Slicer}} + \text{Material Costs}_{\text{in Hours}} \quad \text{(I.L. 3)}$$

The time required to make the Bologna Slicer was two 7.5 hour days (15 hours). There were no material costs associated with developing the calibration test. This is because the Bologna Slicer was made with scrap wood from sewing machine shipping crates. The reciprocating knife, used in the Bologna Slicer, is found in a majority of cutting rooms, and was borrowed for use in the Bologna Slicer. No fabric costs were incurred because scrap fabric was used. In industrial environments, the Bologna Slicer could even allow mechanics to make calibration bundles from the scrap fabric taken from the actual spreads being prepared for Clupicker processing. Using all this information in Equation I.L. 3 gives:

$$\text{Hours}_{\text{Developing Setup}} = \text{Hours}_{\text{Making Bologna Slicer}} + \text{Material Costs}_{\text{in Hours}} \quad \text{(I.L. 3)}$$

$$= 15 \text{ hours} + 0 \text{ hours} = 15 \text{ hours} \quad \text{(I.L. 4)}$$

Plugging I.L. 4 into I.L. 2 gives:

$$\text{Annual Hours}_{\text{Developing Setup}} = \frac{\text{Hours}_{\text{Developing Setup}}}{6 \text{ years}} \quad \text{(I.L. 2)}$$

$$= \frac{15 \text{ hours}}{6 \text{ years}}$$

$$= 2.5000 \text{ hours/year} \quad \text{(I.L. 5)}$$

The next step required to solve Equation I.L. 1 involves calculating the number of hours spent over the course of one year in setting up the Original Clupickers. The equation for this is:

$$\text{Annual Hours}_{\text{Setup}} = \frac{\text{hours}}{\text{setup}} \times \frac{\text{\# setups}}{\text{day}} \times \frac{\text{5 days}}{\text{week}} \times \frac{\text{49 weeks}}{\text{year}} \qquad \text{(I.L. 6)}$$

In setting up the Original Clupickers, the test team used and reused a diagnostic bundle containing 129 plies of white oxford cloth. From Appendix E it can be seen that each bundle of 129 plies took approximately 25 minutes to prepare and process. With practice and experience, the test team estimated that complete Clupicker setups could be made and confirmed in approximately 15 minutes (50 plies @ 0.1067 S.A.M. = 5.3 minutes plus approximately 10 minutes for setup and evaluation) or 0.25 hours. So,

$$\frac{\text{hours}}{\text{setup}} = 0.25 \text{ hours} \qquad \text{(I.L. 7)}$$

Efforts then focused on determining how many Original Clupicker adjustments are *truly* necessary each day in the typical shirt manufacturing facility? This question is extremely difficult to answer.

Keith Daniel's questionnaire showed that some manufacturing facilities make constant adjustments while others require very few. There are many factors which may contribute to such circumstances, but the test team's experience suggests that bundle preparation, correct initial adjustment, and fabric variation are the three factors which most likely contribute to the *perceived* need for Clupicker adjustments. The issue here is how many Clupicker adjustments are truly necessary versus how many Clupicker adjustments are perceived as necessary? In other words, how many mispicks are caused by the Clupickers versus how many mispicks are caused by bundle related problems?

The Clupicker experiment was only designed to compare the performance of the Modified Clupickers against the Original Clupickers, and it was shown that the Modified Clupickers perform better than the Original Clupickers. The Clupicker experiment was not designed to answer the questions "How many mispicks are caused by the Clupickers versus how many mispicks are caused by bundle related problems?" Unfortunately,

there is no comprehensive data relating bundle preparation with Clupicker performance.

Anyone who has tried to use a Clupicker system will find that ply-to-ply attraction, edge-fiber entanglement, edge-fiber fusing, and ply-to-ply misalignment all have an affect on Clupicker performance, but no information is available that relates levels of bundle errors with levels of Clupicker performance. Even if such information did exist it would only have general applicability due to the enormous variations in bundle preparation, handling, and fabric content that take place in manufacturing environments.

In any event, it was necessary to estimate the number of times Clupicker adjustments would be made each day in a typical shirt manufacturing operation. Based on Keith Daniel's questionnaire responses, it was determined that most plants would feel the need to adjust the Original Clupickers when ever major fabric change that took place (whether Clupicker adjustments were truly necessary or not).

Combining this knowledge with the knowledge that more and more manufacturing is going to smaller and smaller lot sizes, CAR decided to analyze the Clupicker indirect labor costs for a range of daily style change requirements from one style change per day to twelve style changes a day. In this example of the AMCIA Indirect Labor worksheet, it was assumed that one major style change occurred each working day throughout the year. In other words:

$$\frac{\text{\# setups}}{\text{day}} = \frac{\text{1 setup}}{\text{day}} \qquad \text{(I.L. 8)}$$

Although not needed for the Indirect Labor Worksheet, Equations I.L. 7 and I.L. 8 can be conveniently used to calculate:

$$\text{Hours}_{\text{Setup}} = \frac{\text{hours}}{\text{setup}} \times \frac{\text{\# setups}}{\text{day}} \qquad \text{(I.L. 9)}$$

$$= 0.25 \text{ hours} \times \frac{\text{1 setup}}{\text{day}}$$

$$= 0.25 \text{ hours} \qquad \text{(I.L. 10)}$$

Equations I.L. 7 and I.L. 8 can also be substituted into Equation I.L. 6 yielding:

$$\text{Annual Hours}_{\text{Setup}} = \frac{\text{hours}}{\text{setup}} \times \frac{\text{\# setups}}{\text{day}} \times \frac{\text{5 days}}{\text{week}} \times \frac{\text{49 weeks}}{\text{year}} \qquad \text{(I.L. 6)}$$

$$= \frac{\text{0.2500 hours}}{\text{setup}} \times \frac{\text{1 setup}}{\text{day}} \times \frac{\text{5 days}}{\text{week}} \times \frac{\text{49 weeks}}{\text{year}}$$

$$= \text{61.25 hours/year} \qquad \text{(I.L. 11)}$$

Taking the values generated in Equations I.L. 5 and I.L. 11 and substituting into Equation I.L. 1:

$$\text{Annual Hours} = \text{Annual Hours}_{\text{Developing Setup}} + \text{Annual Hours}_{\text{Setup}} \qquad \text{(I.L. 1)}$$

$$= \text{2.5 hours/year} + \text{61.25 hours/year}$$

$$= \text{63.75 hours/year} \approx \text{64 hours/year*} \qquad \text{(I.L. 12)}$$

* 64 hours/year was entered into the Indirect Labor Worksheet because AMCIA does not use WYSIWYG (See Company Data Sheet, *Interest on a 3 Month U.S. Treasury Bill*).

This is the annual number of hours indirect labor (mechanics) must spend setting up the Clupickers assuming one major style change occurs each day.

Annual Indirect Labor Regular Hours , Projected

Up to this point all of the calculations applied to the Original Clupicker only. Even though the test team did not have to adjust the Modified Clupickers, the assumption that the Modified Clupickers would never need adjusting is simply untrue.

Recognizing that Clupicker adjustments would be made when mispicks became an inconvenience, and assuming that the ratio of Original Clupicker adjustments to Modified Clupicker adjustments would be inversely proportional to Clupicker performance (i.e. as Clupicker performance went up the number of adjustments went down), the following

equation was constructed for calculating the setup time for the Modified Clupickers:

$$\text{Setup Hours}_{\text{Modified}} = \text{Setup Hours}_{\text{Original}} \times \left(\frac{\text{Performance}_{\text{Modified}}}{\text{Performance}_{\text{Original}}} \right)^{-1}$$

(I.L. 13)

Using simple substitution:

$$\text{Setup Hours}_{\text{Original}} = \text{Annual Hours}_{\text{Setup, Original}} \qquad \text{(I.L. 14)}$$

$$= 61.25 \text{ hours/year} \qquad \text{(I.L. 11)}$$

Again using substitution:

$$\text{Performance}_{\text{Modified}} = \frac{\text{Ply}_{\text{Pick}}}{\text{Ply}_{\text{Available}}} \qquad \text{(I.L. 15)}$$

$$= 99.4015\% \qquad \text{(D.L. 28)*}$$

* See Table D.L.-1 in the Direct Labor Worksheet.

And once again using substitution:

$$\text{Performance}_{\text{Original}} = \frac{\text{Ply}_{\text{Pick}}}{\text{Ply}_{\text{Available}}} \qquad \text{(I.L. 16)}$$

$$= 97.0373\% \qquad \text{(D.L. 10)}$$

Now, plugging values from Equations I.L. 11, D.L. 29 and D.L. 10 into

Equation I.L. 13 yields:

$$\text{Setup Hours}_{\text{Modified}} = \frac{61.25 \text{ hours}}{\text{year}} \text{ x } \left(\frac{99.40\%}{97.04\%} \right)^{-1}$$

$$= 59.80 \text{ hours/year} \qquad \text{(I.L. 17)}$$

And finally using the same type of simple substitution used in I.L. 14:

$$\text{Annual Hours}_{\text{Setup, Modified}} = \text{Setup Hours}_{\text{Modified}}$$

$$= 59.80 \text{ hours/year} \qquad \text{(I.L. 18)}$$

Taking the values generated in Equations I.L. 5 and I.L. 15 and substituting into Equation I.L. 1:

$$\text{Annual Hours} = \text{Annual Hours}_{\text{Developing Setup}} + \text{Annual Hours}_{\text{Setup}} \qquad \text{(I.L. 1)}$$

$$= 2.5 \text{ hours/year} + 59.80 \text{ hours/year}$$

$$= 62.30 \text{ hours/year} \approx 62 \text{ hours/year*} \qquad \text{(I.L. 19)}$$

* 62 hours/year was entered into the Indirect Labor Worksheet because AMCIA does not use WYSIWYG (See Company Data Sheet, *Interest on a 3 Month U.S. Treasury Bill*).

Based on Equation I.L. 19 the decrease in Modified Clupicker mispicks does not have a substantial impact on the perceived need to adjust the Clupickers. This has serious implications for all Clupickers because it shows that one of the major costs associated with using the Clupickers (the indirect labor costs) are not dramatically affected by performance improvements of the Clupickers.

Confidence

Assigning a confidence estimate of 90%, completes this worksheet example.

It is very important to note that the Indirect Labor worksheet has a substantial impact on the Direct Labor worksheet. This is because whenever Clupicker adjustments must be made, the direct labor efficiency

goes down (see the Direct Labor worksheet), while the amount of indirect labor goes up. In basic terms, what this means is that time spent adjusting the Clupickers is time taken away from direct labor and shifted to indirect labor.

Materials

According to the AMCIA manual, this worksheet "... accounts for cash flows related to materials other than fabric." Since values in this worksheet will vary from company to company, and since savings associated with reduced scrap were accounted for in the Quality Related Costs worksheet, the Materials worksheet was left blank.

MATERIALS

	Present	Projected
Material cost (\$/unit): (Excludes fabric cost)		

Summary of Materials

After-tax cash flows:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Confidence in this estimate (1-100):

Present value:

END OF 'MATERIALS' WORKSHEET

Maintenance

This worksheet accounts for cash flows due to maintenance, parts and supplies, and service contracts. This worksheet does not include the indirect labor costs associated with mechanics. The cost of mechanics is accounted for in the Indirect Labor Worksheet.

MAINTENANCE

Your estimate of maintenance expenses should include:
- routine maintenance,
- parts and supplies, and
- service contracts.

Estimate of the change in total annual maintenance expenses:
NOTE: Negative numbers indicate reductions.

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Summary of Maintenance

After-tax cash flows:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Confidence in this estimate (1-100):

Present value:

END OF MAINTENANCE WORKSHEET

Since no reliable data was available, the test team decided to leave this worksheet blank.

Quality Related Costs

QUALITY RELATED COSTS

(Costs are positive numbers. Projected % Change is negative for a decrease in costs.)

	Present Cost	Projected % Change	Projected $ Change
Average annual labor cost of repair and reinspection for products affected by this decision:	$ 829	-78 %	-647
Average annual cost of scrapped products:	$ 608	-78 %	-474
Annual net cost of seconds: (Include manufacturing costs minus revenues received for seconds.)	$	%	
Annual excess cost due to repaired, scrapped or second products: (This cost may include process delays or overtime to meet normal production, and should be in addition to overtime cost entered on the Indirect Labor Worksheet.)	$	%	

Summary of Quality Related Costs

After-tax cash flows:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
729	747	765	783	801	820

Confidence in this estimate (1-100): 90

Present value: 3412

END OF 'QUALITY RELATED COSTS' WORKSHEET

Average Annual Labor Cost of Repair and Reinspection, Present Cost

Calculating the number of mispicks a Clupicker makes is not the same as calculating the number of pieces that need repair. This is because not all mispicks lead to production errors and rework. In fact, the test team's experience indicates that most mispicks lead to processing delays and not assembly errors. Unfortunately, the information collected in the Clupicker Experiment does not correlate mispicks with hemming errors because the pieces picked were never processed through the Hemmer. The only way to correlate mispicks with repair work was to make a performance assumption.

In the AMCIA analysis the test team made the following **unsupported** assumption: 90% of all mispicks do not lead to defective product. 9% of all mispicks lead to defective product that can be repaired. 1% of all mispicks produce product damage that is beyond repair (see the "Average Annual Cost of Scrapped Products, Present" field below).

To calculate the daily cost of repairs and reinspection, the following equation was used:

$$\frac{\text{Cost}_{\text{Repair and Reinspection}}}{\text{Work Day}} = \frac{\text{Cost}_{\text{Repair}}}{\text{Work Day}} + \frac{\text{Cost}_{\text{Reinspection}}}{\text{Work Day}} \qquad \text{(Q.R.C. 1)}$$

The hemming of shirt fronts is one of the first assembly processes in the manufacture of dress shirts. There are any number of subsequent operations which can be used to inspect the shirt fronts before additional assembly processes take place. All manufacturers should recognize that because it is harder to process parts that are not within tolerance, the time spent producing defective items is greater than the time spent producing correct items. Assuming that a company purchasing Clupickers is committed to quality, this AMCIA analysis assumes that every operation down stream of hemming serves as an inspection station. Based on this assumption:

$$\frac{\text{Cost}_{\text{Reinspection}}}{\text{Work Day}} = \$0.00 \qquad \text{(Q.R.C. 2)}$$

To calculate the daily cost of repairs the following equation was used:

$$\frac{\text{Cost}_{\text{Repairs}}}{\text{Work Day}} = \frac{\text{\# Repairs}}{\text{Work Day}} \times \frac{\text{Time}}{\text{Repair}} \times \frac{\$}{\text{Time}_{\text{Direct Labor}}} \qquad \text{(Q.R.C. 3)}$$

The first step in solving Equation Q.R.C. 3 involves determining the number of repairs that occur during a typical work day. Using the assumption that 9% of all mispicks lead to repairs:

$$\frac{\text{\# Repairs}}{\text{Work Day}} = \frac{\text{\# Mispicks}}{\text{Work Day}} \times 9\% \qquad \text{(Q.R.C. 4)}$$

The next step in solving Equation Q.R.C. 3 involves calculating the number of mispicks that occur in a working day. The following equation serves as

the starting point:

$$\frac{\#\ \text{Mispicks}}{\text{Work Day}} = \left(\frac{\#\ \text{Picks}}{\text{Second}}\right)_{\text{Maximum}} \text{x} \ \frac{\#\ \text{Seconds}_{\text{Spent Mispicking}}}{\text{Work Day}} \qquad \text{(Q.R.C. 5)}$$

Calculating the maximum number of picks per second is simply a matter of working backward from the maximum number of picks that can occur during a day's production.

$$\left(\frac{\#\ \text{Picks}}{\text{Second}}\right)_{\text{Maximum}} = \text{Production}_{\text{Maximum}} \qquad \text{(Q.R.C. 6)}$$

$$= \frac{4{,}500 \text{ units}}{8 \text{ hours}} \qquad \text{(D.L. 2)}$$

$$= \frac{4{,}500 \text{ units}}{28{,}800 \text{ seconds}} \qquad \text{(Q.R.C. 7)}$$

The next missing component of Equation Q.R.C. 5 is the amount of time spent mispicking during a typical work day.

$$\frac{\#\ \text{Seconds}_{\text{Spent Mispicking}}}{\text{Work Day}} = \frac{\#\ \text{Seconds}_{\text{Spent Mispicking}}}{\text{Ply}} \text{x} \ \frac{\#\ \text{Plies}_{\text{Processed}}}{\text{Work Day}} \qquad \text{(Q.R.C. 8)}$$

Using simple substitution:

$$\frac{\#\ \text{Seconds}_{\text{Spent Mispicking}}}{\text{Ply}} \equiv \frac{\text{Time Mispick}}{\text{Ply}_{(1-\%)}} \qquad \text{(Q.R.C. 9)}$$

$$= \frac{0.1896 \text{ sec}}{\text{ply}} \qquad \text{(D.L. 14)}$$

The number of plies processed per work day is equivalent to the daily production.

$$\frac{\text{\# Plies}_{\text{Processed}}}{\text{Work Day}} \equiv \text{Production}_{\text{Actual}} \qquad \text{(Q.R.C. 10)}$$

$$= \frac{\text{3,805 units}}{\text{work day}} \qquad \text{(D.L. 26)}$$

Since plies and units are the same thing Equation Q.R.C. 5 can be expressed as:

$$\frac{\text{\# Mispicks}}{\text{Work Day}} = \frac{\text{4,500 plies}}{\text{28,800 sec}} \times \frac{\text{0.1896 sec}}{\text{ply}} \times \frac{\text{3,805 plies}}{\text{work day}}$$

$$= \frac{\text{112.7231 plies}}{\text{work day}} \qquad \text{(Q.R.C. 11)}$$

Returning to Equation Q.R.C. 4,

$$\frac{\text{\# Repairs}}{\text{Work Day}} = \frac{\text{\# Mispicks}}{\text{Work Day}} \times 9\% \qquad \text{(Q.R.C. 4)}$$

$$= \frac{\text{112.7231 plies}}{\text{work day}} \times 9\%$$

$$= \frac{\text{10.1451 plies}}{\text{work day}} \qquad \text{(Q.R.C. 12)}$$

Assuming that each repair takes a total of 5 minutes from the time it is

detected to the time it is ready to reloaded,

$$\frac{\text{Time}}{\text{Repair}} = \frac{5 \text{ min.}}{\text{repair}} \qquad \text{(Q.R.C. 13)}$$

The only piece of information missing from Equation Q.R.C. 3 is the cost of direct labor's time.

$$\frac{\$}{\text{Time}_{\text{Direct Labor}}} = \frac{\$4.00}{\text{hour}} = \frac{\$4.00}{60 \text{ min.}} \qquad \text{(Q.R.C. 14)}$$

Now, using Equations Q.R.C. 12, Q.R.C. 13, and Q.R.C. 14 it is possible to solve Equation Q.R.C. 3.

$$\frac{\text{Cost}_{\text{Repairs}}}{\text{Work Day}} = \frac{\text{\# Repairs}}{\text{Work Day}} \times \frac{\text{Time}}{\text{Repair}} \times \frac{\$}{\text{Time}_{\text{Direct Labor}}} \qquad \text{(Q.R.C. 3)}$$

$$= \frac{10.1451 \text{ plies}}{\text{work day}} \times \frac{5 \text{ min.}}{\text{repair}} \times \frac{\$4.00}{60 \text{ min.}}$$

$$= \frac{10.1451 \text{ plies}}{\text{work day}} \times \frac{5 \text{ min.}}{\text{repair}} \times \frac{\$4.00}{60 \text{ min.}}$$

$$= \frac{\$3.3817}{\text{day}} \qquad \text{(Q.R.C. 15)}$$

Now, plugging Equation Q.R.C. 2 and Q.R.C. 15 into Equation Q.R.C. 1 yields:

$$\frac{\text{Cost}_{\text{Repair and Reinspection}}}{\text{Work Day}} = \frac{\text{Cost}_{\text{Repair}}}{\text{Work Day}} + \frac{\text{Cost}_{\text{Reinspection}}}{\text{Work Day}} \qquad \text{(Q.R.C. 1)}$$

$$= \frac{\$3.3817}{\text{day}} + \frac{\$0.00}{\text{day}}$$

$$= \frac{\$3.3817}{\text{day}} \qquad \text{(Q.R.C. 16)}$$

To calculate the average annual labor cost of repair and reinspection involved using the following equation.

$$\frac{\text{Cost}_{\text{Repair and Reinspection}}}{\text{year}} = \frac{\text{Cost}_{\text{Repair and Reinspection}}}{\text{work day}} \times \frac{5\text{ days}}{\text{week}} \times \frac{49\text{ weeks}}{\text{year}}$$

$$= \frac{\$828.62^{*}}{\textit{year}} \approx \frac{\$829^{**}}{\textit{year}} \qquad \textit{(Q.R.C. 17)}$$

* See note on page I-3.

** $829 was entered into the Quality Related Costs Worksheet because AMCIA does not use WYSIWYG (See Company Data Sheet, *Interest on a 3 Month U.S. Treasury Bill*).

Average Annual Labor Cost of Repair and Reinspection, Projected % Change

The easiest way to determine the projected % change in the annual labor costs of repair and reinspection involves recognizing that:

$$\frac{\text{Cost}_{\text{Repair and Reinspection}}}{\text{Work Day}} \propto \frac{\#\text{ Mispicks}}{\text{Work Day}} \qquad \text{(Q.R.C. 18)}$$

In other words the two variables above are directly proportional to each other. Equation Q.R.C. 18 implies that

$$\Delta \text{ Cost}_{\text{Repair and Reinspection}} = \Delta \text{ \# Mispicks} \qquad \text{(Q.R.C. 19)}$$

where:

$$\Delta \text{ \# Mispicks} = \frac{\text{\# Mispicks}_{\text{Projected}} - \text{\# Mispicks}_{\text{Present}}}{\text{\# Mispicks}_{\text{Present}}} \qquad \text{(Q.R.C. 19)}$$

Using Equation Q.R.C. 5 it is possible to project the number of mispicks that will occur if the Modified Clupickers are installed.

$$\frac{\text{\# Mispicks}}{\text{Work Day}} = \left(\frac{\text{\# Picks}}{\text{Second}}\right)_{\text{Maximum}} \text{x} \ \frac{\text{\# Seconds}_{\text{Spent Mispicking}}}{\text{Work Day}} \qquad \text{(Q.R.C. 5)}$$

where

$$\left(\frac{\text{\# Picks}}{\text{Second}}\right)_{\text{Maximum}} = \text{Production}_{\text{Maximum}} \qquad \text{(Q.R.C. 6)}$$

$$= \frac{\text{4,500 units}}{\text{8 hours}} \qquad \text{(D.L. 2)}$$

$$= \frac{\text{4,500 units}}{\text{28,800 seconds}} \qquad \text{(Q.R.C. 7)}$$

and:

$$\frac{\text{\# Seconds}_{\text{Spent Mispicking}}}{\text{Work Day}} = \frac{\text{\# Seconds}_{\text{Spent Mispicking}}}{\text{Ply}} \ \text{x} \ \frac{\text{\# Plies}_{\text{Processed}}}{\text{Work Day}} \qquad \text{(Q.R.C. 8)}$$

Using simple substitution:

$$\frac{\#\ \text{Seconds}_{\text{Spent Mispicking}}}{\text{Ply}} \equiv \frac{\text{Time Mispick}}{\text{Ply}_{(1-\%)}} \qquad \text{(Q.R.C. 9)}$$

$$= \frac{0.03830\ \text{sec}}{\text{ply}} \qquad \text{(D.L. 33)*}$$

* From Table D.L.-1 in the Direct Labor Worksheet description.

The number of plies processed per work day is equivalent to the daily production.

$$\frac{\#\ \text{Plies}_{\text{Processed}}}{\text{Work Day}} \equiv \text{Production}_{\text{Actual}} \qquad \text{(Q.R.C. 10)}$$

$$= \frac{4{,}163\ \text{units}}{\text{work day}} \qquad \text{(D.L. 39)}$$

Since plies and units are the same thing Equation Q.R.C. 5 can be expressed as:

$$\frac{\#\ \text{Mispicks}}{\text{Work Day}} = \frac{4{,}500\ \text{plies}}{28{,}800\ \text{sec}} \times \frac{0.03830\ \text{sec}}{\text{ply}} \times \frac{4{,}163\ \text{plies}}{\text{work day}}$$

$$= \frac{24.9130\ \text{plies}}{\text{work day}} \qquad \text{(Q.R.C. 20)}$$

Using this value along the with the value obtained in Equation Q.R.C. 11,

$$\Delta \# \text{Mispicks} = \frac{\# \text{Mispicks}_{\text{Projected}} - \# \text{Mispicks}_{\text{Present}}}{\# \text{Mispicks}_{\text{Present}}} \qquad \text{(Q.R.C. 19)}$$

$$= \frac{24.9130 \text{ plies} - 112.7231 \text{ plies}}{112.7231 \text{ plies}}$$

$$= -\mathit{77.90\%} \qquad \textbf{\textit{(Q.R.C. 21)**}}$$

And because:

$$\Delta \text{ Cost}_{\text{Repair and Reinspection}} = \Delta \# \text{Mispicks} \qquad \text{(Q.R.C. 19)}$$

it follows that:

$$\boldsymbol{\Delta \textit{ Cost}_{\textit{Repair and Reinspection}} = -\ \textit{77.90\%} \approx -\ \textit{78\%* (Q.R.C. 22)**}}$$

* − 78% was entered into the Quality Related Costs Worksheet because AMCIA does not use WYSIWYG (See Company Data Sheet, *Interest on a 3 Month U.S. Treasury Bill*).

** In the Clupicker Programs in Appendix J, the value - 78% was attributed to Equation Q.R.C. 21 because, from a programming perspective, Equation Q.R.C. 22 is redundant.

Average Annual Cost of Scrapped Products, Present Cost

As explained in the first section of this worksheet, the test team made the following **unsupported** assumption: 90% of all mispicks do not lead to defective product. 9% of all mispicks lead to defective product that can be repaired. 1% of all mispicks produce product damage that is beyond repair.

To calculate the daily cost of scrapped products, the following equation was used:

$$\frac{\text{Cost}_{\text{Scrapping}}}{\text{Work Day}} = \frac{\text{Cost Labor}_{\text{Scrapping}}}{\text{Work Day}} + \frac{\text{Cost Fabric}_{\text{Scrapping}}}{\text{Work Day}} \qquad \text{(Q.R.C. 23)}$$

To calculate the daily cost of labor associated with scrap, the following equation was used:

$$\frac{\text{Cost Labor}_{\text{Scrapping}}}{\text{Work Day}} = \frac{\text{\# Scrapped Pieces}}{\text{Work Day}} \times \frac{\text{Time}}{\text{Replacement}} \times \frac{\$}{\text{Time}_{\text{Direct Labor}}}$$

(Q.R.C. 24)

Calculating the number of scrapped pieces per day involves using the assumption that 1% of all mispicks lead to scrapped parts:

$$\frac{\text{\# Scrapped Pieces}}{\text{Work Day}} = \frac{\text{\# Mispicks}}{\text{Work Day}} \times 1\% \qquad \text{(Q.R.C. 25)}$$

The next step involves plugging the information from Equation Q.R.C. 11 into Equation Q.R.C. 25 to get:

$$\frac{\text{\# Scrapped Pieces}}{\text{Work Day}} = \frac{112.7231 \text{ plies}}{\text{Work Day}} \times 1\%$$

$$= \frac{1.1272 \text{ plies}}{\text{work day}} \qquad \text{(Q.R.C. 26)}$$

Knowing the difficulties associated with identifying, cutting, and replacing damaged parts so that they stay color matched, the test team made the assumption that each part replacement takes 15 minutes from the time the faulty part is detected to the time its replacement is ready to be loaded.

$$\frac{\text{Time}}{\text{Replacement}} = \frac{15 \text{ min.}}{\text{replacement}} \qquad \text{(Q.R.C. 27)}$$

The only piece of information missing from Equation Q.R.C. 24 is the cost

of direct labor's time.

$$\frac{\$}{\text{Time}_{\text{Direct Labor}}} = \frac{\$4.00}{\text{hour}} = \frac{\$4.00}{60 \text{ min.}} \qquad \text{(Q.R.C. 14)}$$

Now, using Equations Q.R.C. 26, Q.R.C. 27, and Q.R.C. 14 it is possible to solve Equation Q.R.C. 24.

$$\frac{\text{Cost Labor}_{\text{Scrapping}}}{\text{Work Day}} = \frac{\text{\# Scrapped Pieces}}{\text{Work Day}} \text{ x } \frac{\text{Time}}{\text{Replacement}} \text{ x } \frac{\$}{\text{Time}_{\text{Direct Labor}}}$$

$$= \frac{1.1272 \text{ plies}}{\text{work day}} \text{ x } \frac{15 \text{ min.}}{\text{repair}} \text{ x } \frac{\$4.00}{60 \text{ min.}}$$

$$= \frac{\$1.1272}{\text{work day}} \qquad \text{(Q.R.C. 28)}$$

The only piece of information preventing Equation Q.R.C. 23 from being solved is the daily cost of the fabric used in the replacement parts. This can be calculated using the following equation.

$$\frac{\text{Cost Fabric}_{\text{Scrapping}}}{\text{Work Day}} = \frac{\text{\# Scrapped Pieces}}{\text{Work Day}} \text{ x } \frac{\text{Sq. Yds. Fabric}}{\text{Scrapped Piece}} \text{ x } \frac{\text{Cost of Fabric}}{\text{Sq. Yd.}}$$

(Q.R.C. 29)

Equation Q.R.C. 26 already calculated the number of scrapped pieces per day. Using CAR's Microdynamics marker making system the number of square yards of fabric in a men's size 15 dress shirt was estimated at 0.3 square yards. The cost of the dress shirt fabric was estimated at $4.00 per square yard.

Plugging these values into Equation Q.R.C. 29 yields:

$$\frac{\text{Cost Fabric}_{\text{Scrapping}}}{\text{Work Day}} = \frac{\text{\# Scrapped Pieces}}{\text{Work Day}} \times \frac{\text{Sq. Yds. Fabric}}{\text{Scrapped Piece}} \times \frac{\text{Cost of Fabric}}{\text{Sq. Yd.}}$$

$$= \frac{\text{1.1272 plies}}{\text{work day}} \times \frac{\text{0.3000 sq. yd.}}{\text{scrapped piece}} \times \frac{\$4.00}{\text{sq. yd.}}$$

$$= \frac{\$1.3526}{\text{work day}} \qquad \text{(Q.R.C. 30)}$$

Now, plugging Q.R.C. 28 and Q.R.C. 30 into Q.R.C. 1 yields:

$$\frac{\text{Cost }_{\text{Scrapping}}}{\text{Work Day}} = \frac{\text{Cost Labor }_{\text{Scrapping}}}{\text{Work Day}} + \frac{\text{Cost Fabric}_{\text{Scrapping}}}{\text{Work Day}} \qquad \text{(Q.R.C. 23)}$$

$$= \frac{\$1.1272}{\text{work day}} + \frac{\$1.3526}{\text{work day}}$$

$$= \frac{\$2.4798}{\text{work day}} \qquad \text{(Q.R.C. 31)}$$

Using the solution Q.R.C. 31 it is possible to the average annual cost of scrap.

$$\frac{\text{Cost }_{\text{Scrapping}}}{\text{year}} = \frac{\text{Cost }_{\text{Scraping}}}{\text{work day}} \times \frac{\text{5 days}}{\text{week}} \times \frac{\text{49 weeks}}{\text{year}}$$

$$= \frac{\boldsymbol{\$607.65}^{*\text{(see next page)}}}{\textbf{\textit{year}}} \approx \frac{\boldsymbol{\$608}^{**\text{(see next page)}}}{\textbf{\textit{year}}} \qquad \textbf{\textit{(Q.R.C. 32)}}$$

* See note on page I - 3.

** \$608 was entered into the Quality Related Costs Worksheet because AMCIA does not use WYSIWYG (See Company Data Sheet, *Interest on a 3 Month U.S. Treasury Bill*).

Average Annual Cost of Scrapped Products, Projected % Change

The easiest way to determine the projected % change in the annual labor costs of scrapping goods involves recognizing that:

$$\frac{\text{Cost}_{\text{Scrapping}}}{\text{Work Day}} \propto \frac{\text{\# Mispicks}}{\text{Work Day}} \qquad \text{(Q.R.C. 33)}$$

In other words the two variables above are directly proportional to each other. Equation Q.R.C. 33 implies that:

$$\Delta\ \text{Cost}_{\text{Scrapping}} = \Delta\ \text{\# Mispicks} \qquad \text{(Q.R.C. 34)}$$

where:

$$\Delta\ \text{\# Mispicks} = \frac{\text{\# Mispicks}_{\text{Projected}} - \text{\# Mispicks}_{\text{Present}}}{\text{\# Mispicks}_{\text{Present}}} \qquad \text{(Q.R.C. 19)}$$

Since the present number of mispicks was calculated in Equation Q.R.C. 11 and the projected number of mispicks was calculated in Equation Q.R.C. 20, Equation Q.R.C. 19 can be expressed as:

$$\Delta\ \text{\# Mispicks} = \frac{\text{\# Mispicks}_{\text{Projected}} - \text{\# Mispicks}_{\text{Present}}}{\text{\# Mispicks}_{\text{Present}}} \qquad \text{(Q.R.C. 19)}$$

$$= \frac{24.9130 \text{ plies} - 112.7231 \text{ plies}}{112.7231 \text{ plies}}$$

$$= -\ 77.90\% \qquad \text{(Q.R.C. 21)}$$

And because:

$$\Delta \text{ Cost}_{\text{Scrapping}} = \Delta \text{ \# Mispicks} \qquad \text{(Q.R.C. 34)}$$

it follows that:

$$\Delta \text{ Cost}_{\text{Scrapping}} = -\ 77.90\% \approx -\ 78\%^{*} \qquad \text{(Q.R.C. 35)}$$

* − 78% was entered into the Quality Related Costs Worksheet because AMCIA does not use WYSIWYG (See Company Data Sheet, *Interest on a 3 Month U.S. Treasury Bill*).

Not surprisingly, this is the same value as the value expressed in Equation Q.R.C. 22.

Annual Net Cost of Seconds

The hemming of shirt fronts is one of the first assembly processes in the manufacture of dress shirts. As explained earlier, there are any number of subsequent operations which can be used to inspect the shirt fronts before additional assembly processes take place. This analysis assumes that companies interested in investing in Clupicker technology recognize the need to remain competitive and hence recognizes the foolishness of producing second quality goods for the same amount (or more) effort than producing first quality goods. In other words, this analysis assumes the production of seconds is not allowed to occur.

Annual Excess Cost Due to Repaired, Scrapped or Second Products

According to the AMCIA worksheet, "This cost may include process delays or overtime to meet normal production, and should be in addition to (the) overtime cost entered on the Indirect Labor Worksheet." This means that the Annual Excess Cost field is used to anticipate costs associated with repaired and scrapped products. These anticipated costs would be expected, but their occurrence would be random and difficult to quantify. Basically Annual Excess Cost is used to make the Quality Related Costs more conservative. Since the information used to calculate the Quality Related Costs has been based on a rigorous theoretical model, taking into account all major eventualities, the Annual Excess Cost field was left blank.

Inventory

The Inventory worksheet was left blank because plant-to-plant manufacturing variations made a generally applicable inventory worksheet impossible to formulate. The only general statement that can be made is that the largest impact a Jet Sew Feeder can have on inventory levels occurs when the Feeder is a known production bottleneck.

INVENTORY

Your sales estimate with the current technology for the products affected by this decision is:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
9322620	9555686	9788751	10021817	10254882	10487948

Implied average throughput rate ($/week): 202149

Normal average inventory level (dollars):

Implied throughput time (weeks):
If this seems unrealistic, adjust your sales estimates and/or your inventory estimate.

Expected % change in inventory level:
(Negative percentage indicates a decrease.)

Expected new throughput time (weeks):
If it seems unrealistic, adjust estimates before continuing.

Estimated change in inventory-related recurring cash flows, in dollars (e.g. warehouse rental charges, insurance, etc.):

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Summary of Inventory

After-tax cash flows:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Confidence in this estimate (1-100):

Present value:

END OF 'INVENTORY' WORKSHEET

Fabric Utilization

The fabric utilization worksheet is used to calculate the fabric savings associated with the decision to purchase a piece of equipment. This worksheet does not take into account savings due to a reduction in rework and an associated reduction in scrap. Reductions in rework and scrap are accounted for in the Quality Related Costs worksheet. Since the Jet Sew Feeders are designed to minimize rework, but are not specifically designed to maximize fabric utilization, the Fabric Utilization worksheet was left blank.

FABRIC UTILIZATION

Number of yards per unit:

Average cost in dollars per yard:

Estimated number of units to be produced using the current technology (units/year):

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
932262	932262	932262	932262	932262	932262

Estimated fabric cost per year (dollars/year):

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Expected % fabric savings using the new technology:
(Positive number indicates a saving.)

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Fabric savings:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Summary of Fabric Utilization

After-tax cash flows:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Confidence in this estimate (1-100):

Present value:

End of Fabric Utilization Worksheet

Miscellaneous

This worksheet is used to estimate cash flows related to miscellaneous categories as defined by the user. Since the worksheet is user dependent, it was left blank.

MISCELLANEOUS

Flow #1 Name: Confidence (1-100): %

Estimated before-tax cash flows:

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

After-tax cash flows:

Present value of after-tax cash flows: dollars

Flow #2 Name: Confidence (1-100): %

Estimated before-tax cash flows:

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

After-tax cash flows:

Present value of after-tax cash flows: dollars

Flow #3 Name: Confidence (1-100): %

Estimated before-tax cash flows:

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

After-tax cash flows:

Present value of after-tax cash flows: dollars

Flow #4 Name: Confidence (1-100): %

Estimated before-tax cash flows:

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

After-tax cash flows:

Present value of after-tax cash flows: dollars

Flow #5 Name: Confidence (1-100): %

Estimated before-tax cash flows:

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

After-tax cash flows:

Present value of after-tax cash flows: dollars

Total Miscellaneous after-tax cash flows (in dollars):

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Present value of total: dollars

END OF 'MISCELLANEOUS' WORKSHEET

Quality Revenues

This worksheet is used to estimate the increase in revenue related to the ability to raise the unit price or the production level as a result of a better quality reputation. Since the ability to raise prices depends on the market being supplied, this worksheet was deemed too specific, and was left blank.

It should be noted, however, that when properly maintained, Jet Sew Feeders, used in conjunction with automated sewing equipment can substantially improve quality and thus contribute to increase production levels as a result of a better quality reputation. Not only that, the Feeders can increase production levels in general. Increased production capacity due to a machine purchase is considered in the Direct Labor worksheet.

It is important to note that this worksheet is not the same as the Quality Related Costs worksheet.

QUALITY REVENUES

Estimated average unit sale price of the product with the current technology (in dollars):

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
10.00	10.25	10.50	10.75	11.00	11.25

Anticipated change in average unit sale price due to better quality (in dollars):

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Estimated number of units to be produced using the current technology:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
932262	932262	932262	932262	932262	932262

Anticipated change in the number of units to be produced due to better quality:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Summary of Quality Revenues

After-tax cash flows:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Confidence in this estimate (1-100):

Present value:

END OF 'QUALITY REVENUES' WORKSHEET

Response-Time Revenues

This worksheet is used to estimate the increase in revenue related to the ability to raise the unit price or the production level as a result of shorter response times.

As with the Quality Revenues worksheet, the Jet Sew Feeder has the potential of substantially impacting production, by dramatically reducing throughput times. It has been CAR's experience, however, that in a majority of manufacturing environments the increase in throughput generated by Jet Sew Feeders is often buried under inefficiencies associated with other manufacturing processes. These manufacturing processes, such as the bundle system, frequently have a greater impact on response-time than the Jet Sew Feeders. With this in mind, CAR decided to leave the Response-time worksheet blank.

RESPONSE-TIME REVENUES

Estimated average unit sale price of the product with the current technology (in dollars):

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
10.00	10.25	10.50	10.75	11.00	11.25

Anticipated change in average unit sale price due to better response time (in dollars):

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Estimated number of units to be produced using the current technology:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
932262	932262	932262	932262	932262	932262

Anticipated change in the number of units to be produced due to better response time:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Summary of Response-time Revenues

After-tax cash flows:

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6

Confidence in this estimate (1-100):

Present value:

END OF RESPONSE-TIME REVENUES' WORKSHEET

Appendix J - Clupicker Programs

Complete Calculation Sequence Derived from Appendix I

Note:

- The "Calculation Values", shown in plain text in the table below, were taken from Appendix I which is based on Scenario 01.b from Appendix M.
- The "Calculation Values" shown in ***bold italics*** were calculated using Program #1 in this appendix. Due to a calculator failure, however, Program #1 had to be rewritten as Program #2. Although the program output is the same, Program #2's storage register names begin with the letters "ST" (short for storage register). For example: the storage register named "00" in Program #1 is called "ST00" in Program #2.

Calculation Sequence Page 1 of 3 [Values in ***bold italics*** are calculated using a Clupicker Program and input into the corresponding AMCIA worksheet cell(s) (see Appendix I).]				
Step	Calculation #	Program Storage Register*	Calculation I.D. (Appendix I)	Calculation Values
1 Select Scenario				Appendix M Scenario 01.b
2a Perform Initial Direct Labor Calculations Original Clupickers	***01***	***00***	***S.A.M.***	***0.1067 min./unit***
	02	***06***	***Base Rate***	***$ 0.0667/min.***
	03	07	(D.L. 10)	%
	04	08	(D.L. 11)	sec./ply
	05	09	(D.L. 13)	%
	06	10	(D.L. 14)	sec./ply
	07	11	(D.L. 18)	sec./ply
	08	12	(D.L. 20)	sec./ply
	09		*(I.L. 10)*	sec.
	10		(D.L. 24)'	sec.
	11	15	(D.L. 26)	units/day
	12	***16***	***(D.L. 27)***	***84.5589 %***
* See Clupicker Programs.				

Calculation Sequence Page 2 of 3
[Values in ***bold italics*** are calculated using a Clupicker Program and input into the corresponding AMCIA worksheet cell(s) (see Appendix I).]

Step	Calculation #	Program Storage Register*	Calculation I.D. (Appendix I)	Calculation Values For Scenario 01.b
2b Perform Initial Direct Labor Calculations Modified Clupickers	13	17	(D.L. 28)	%
	14	18	(D.L. 32)	sec./ply
	15	19	(D.L. 29)	%
	16	20	(D.L. 33)	sec./ply
	17		(D.L. 34)	sec./ply
	18	22	(D.L. 35)	sec./ply
	19		(D.L. 31)	sec.
	20		(D.L. 37)	sec.
	21	25	(D.L. 39)	units/day
	22	***26***	***(D.L. 40)***	***92.4978 %***
3 Complete Quality Related Costs Worksheet	23	27	(Q.R.C. 11)	plies/day
	24		(Q.R.C. 12)	plies/day
	25		(Q.R.C. 15)	$ /day
	26	***30***	***(Q.R.C. 17)***	***$ 829 /year***
	27		(Q.R.C. 20)	plies/day
	28	***32***	***(Q.R.C. 21)***	- ***78 %***
	29		(Q.R.C. 26)	plies/day
	30		(Q.R.C. 28)	$ /day
	31		(Q.R.C. 30)	$ /day
	32		(Q.R.C. 31)	$ /day
	33	***37***	***(Q.R.C. 32)***	***$ 608 /year***
4 Time Check **(See Chapter 3)**	34		(3. 4)	sec.
	35		(3. 5)	sec.
	36		(3. 7)	sec.
	37		(3. 8)	min.
	38	***42***	***(3. 3)***	***403 min.***
	39	***43***	***(3. 7) + (3. 8)***	***68 min.***
5 Complete Company Data Sheet	***40***	***44***	***(C.D.S. 2)***	***932,262 units/year***

* See Clupicker Programs.

Calculation Sequence Page 3 of 3 [Values in ***bold italics*** are calculated using a Clupicker Program and input into the corresponding AMCIA worksheet cell(s) (see Appendix I).]				
Step	Calculation #	Program Storage Register*	Calculation I.D. (Appendix I)	Calculation Values For Scenario 01.b
6 Complete Direct Labor Worksheet	Calculation Done by AMCIA		Change in production capacity you wish to exploit	74,011 units/year
7 Complete Investment, Installation, and Depreciation Worksheet	***41***	***45***	***(I.I.D. 2)***	***– $ 12,000***
	42	***46***	***(I.I.D. 6)***	***– $ 112***
	43	***47***	***(I.I.D. 8)***	***– $ 356***
8 Indirect Labor Worksheet	None	01	Pay Rate	$ 4.00/hr.
	44	48	(I.L. 11)	hr./yr.
	45	***49***	***(I.L. 12)***	**64 hr./yr.**
	46		(I.L. 17)	hr./yr.
	47	***51***	***(I.L. 19)***	**62 hr./yr.**
9 Calculate Net Present Value from Worksheets	AMCIA		Step 3	$ 3,412
	AMCIA		Step 6	$ 2,253,431
	Appx. J		Step 7	–$ 8,781
	AMCIA		Step 8	$ 29
	Appx. L		$\sum$ NPV	$ 2,248,091
* See Clupicker Program in the Appendices.				

Clupicker Program #1 - Written for a Hewlett Packard 41CV Calculator

Clupicker Program #1. Written for a Hewlett Packard 41CV. Page 1 of 2.	
Program Inputs	Program Outputs
00* = S.A.M.	Direct Labor Worksheet
01 = $/hr	00 = S.A.M., Present
02 = Original Clupicker	00 = S.A.M., Projected
Performance	06 = Base Rate, Present
03 = Modified Clupicker	06 = Base Rate, Projected
Performance	16 = Direct Labor Efficiency, Present
04 = Number of Clupickers	26 = Direct Labor Efficiency,
05 = Number of Setups per Day	Projected
	Quality Related Costs Worksheet
	30 = Avg. Annual Labor, Present
	32 = Projected Change, Labor
	37 = Avg. Annual Scrap, Present
	32 = Projected Change, Scrap
	Time Check
	42 = Time Available for Repairs
	43 = Time Required for Repairs
	Company Data Sheet
	44 = Est. # Units to be Produced
	Investment, Installation, and Depreciation
	45 = Investment Expense
	- 45 = Original Value of New
	Equipment
	46 = Retraining Expense
	47 = Installation Expense
	Indirect Labor Worksheet
	02 = Indirect Labor Payrate, Present
	02 = Indirect Labor Payrate,
	Projected
	49 = Annual Hours, Present
	51 = Annual Hours, Projected
* Storage Register Number	

Clupicker Program #1. Written for a Hewlett Packard 41CV. Page 2 of 2.					
Column Numbers (Enter program one column at a time starting with column 1.)					
1	2	3	4	5	6
RCL 00	+	+	0.15625	RCL 27	RCL 17
R/S	STO 12	RCL 18	RCL 20	0.6	/
RCL 01	RCL 05	+	x	x	2.5
60	- 900	RCL 20	RCL 25	STO 43	+
/	x	+	x	R/S	STO 51
STO 06	28,800	RCL 20	RCL 27	RCL 15	f BEEP
R/S	+	+	-	245	f BEEP
RCL 02	RCL 12	STO 22	RCL 27	x	f GTO ..
RCL 04	1/X	RCL 05	/	STO 44	
Y^X	x	900	STO 32	R/S	
STO 07	STO 15	x	R/S	RCL 04	
RCL 00	4500	RCL 07	RCL 01	- 2000	
x	/	RCL 17	0.0025	x	
60	STO 16	/	x	STO 45	
x	R/S	x	0.012	R/S	
STO 08	RCL 03	28,800	+	RCL 01	
1	RCL 04	-	RCL 27	- 28	
ENTER	Y^X	CHS	x	x	
RCL 07	STO 17	RCL 22	245	STO 46	
-	RCL 00	1/X	x	R/S	
STO 09	x	x	STO 37	RCL 04	
RCL 00	60	STO 25	R/S	6	
x	x	4500	RCL 32	/	
60	STO 18	/	R/S	- 356	
x	1	STO 26	RCL 10	x	
STO 10	ENTER	R/S	2	STO 47	
RCL 09	RCL 17	0.15625	x	R/S	
20	-	RCL 10	RCL 08	RCL 05	
x	STO 19	x	+	61.25	
STO 11	RCL 00	RCL 15	RCL 15	x	
0.15	x	x	x	STO 48	
RCL 08	60	STO 27	60	2.5	
+	x	RCL 01	/	+	
RCL 10	STO 20	x	15	STO 49	
+	RCL 19	1.8375	-	R/S	
RCL 11	20	x	f BEEP	RCL 48	
+	x	STO 30	STO 42	RCL 07	
RCL 10	0.15	R/S	R/S	x	

Clupicker Program #2 - Written for a Hewlett Packard 48SX Calculator

Clupicker Program #2. Written for HP48SX Calculator. Page 1 of 2	
Line	Variable Contents and Names
xx	↰ << >> ' *Function* ▶ ↱ →NUM ENTER ' *Storage Location* STO
	Using the generic sample shown above, the following exact keystroke sequence can be used to enter program line 01.
01a	↰ << >> ' α S α T 01 ÷ 60 ▶ ↱ →NUM ENTER ' α S α T 06 STO
	Your calculator should now display
01b	<< 'ST01/60' →NUM >>
	and a new variable called "ST06" should appear in the variable menu.
	For ease of documentation all program lines will be presented in an abbreviated form. For example line 01a and 01b can be shortened to
01c	<< 'ST01 ÷ 60' →NUM >> ST06
02	<< 'ST02 Y^X ST04' →NUM >> ST07
03	<< 'ST07 x ST00 x 60' →NUM >> ST08
04	<< '1 - ST07' →NUM >> ST09
05	<< 'ST09 x ST00 x 60' →NUM >> ST10
06	<< 'ST09 x 20' →NUM >> ST11
07	<< '15 + ST 08 + ST 10 + ST11 + ST 10' →NUM >> ST12
08	<< '(-900 x ST 05 + 28800) x INV(ST 12)' →NUM >> ST15
09	<< 'ST15 ÷ 4500' →NUM >> ST16
10	<< 'ST03 Y^X ST04' →NUM >> ST17
11	<< 'ST17 x ST00 x 60' →NUM >> ST18
12	<< '1 - ST17' →NUM >> ST19
13	<< 'ST19 x ST00 x 60' →NUM >> ST20
14	<< 'ST19 x 20 + 0.15 + ST 18 + ST20 + ST20' →NUM >> ST22
15	<< '-(ST05 x 900 x (ST07 ÷ ST17) - 28800) x INV(ST22)' →NUM >> ST25
16	<< 'ST25 ÷ 4500' →NUM >> ST26
17	<< '0.15625 x ST10 x ST15' →NUM >> ST27
18	<< 'ST27 x ST01 x 1.8375' →NUM >> ST30
19	<< 'INV(ST27) x (0.15625 x ST20 x ST25 - ST27)' →NUM >> ST32
20	<< '(ST01 x 0.0025 + 0.012) x ST27 x 245' →NUM >> ST37
21	<< 'ST10 x 2 + ST08 x ST15 ÷ 60 - 15' →NUM >> ST42
22	<< 'ST27 x 0.6' →NUM >> ST43
23	<< 'ST15 x 245' →NUM >> ST44
24	<< '-2000 x ST04' →NUM >> ST45
25	<< '-28 x ST01' →NUM >> ST46

Clupicker Program #2. Written for HP48SX Calculator. Page 2 of 2	
Line	Variable Contents and Names
26	<< '-356 x (ST04 ÷ 6)' →NUM >> ST47
27	<< 'ST05 + 61.25' →NUM >> ST48
28	<< 'ST48 + 2.5' →NUM >> ST49
29	<< 'ST48 x ST07 ÷ ST17 + 2.5' →NUM >> ST51
30	<< ST06 ST07 ST08 ST09 ST10 ST11 ST12 ST15 ST16 ST17 ST18 ST19 ST20 ST22 ST25 ST26 ST27 ST30 ST32 ST37 ST42 ST43 ST44 ST45 ST46 ST47 ST48 ST49 ST51 >> STPA

Appendix K - Example 01.b Summary

Direct Labor Worksheet

Scenario 01.b			
Direct Labor Worksheet			
Cell Name	Clupicker Program Storage Register	AMCIA Input Value	AMCIA Output
S.A.M.			
	00	0.1067	
	00	0.1067	
Base rate			
Present	06	0.0667	
Projected	06	0.0667	
Direct Labor Efficiency			
Present	16	84.5589	
Projected	26	92.4978	
Excess costs			
Present		0.0000	
Projected		0.0000	
Workers' Comp.			
Present		0.00	
Projected		0.00	
End of Calculation Sequence Step 2. Go forward in AMCIA to Quality Related Costs Worksheet.			
Change in Production Capacity			
Year 1 - 6		74011	
Confidence in this estimate		90	
Present value			$ 2,253,431
End of Calculation Sequence Step 6. Go backward in AMCIA to Investment, Installation, and Depreciation Worksheet.			

Quality Related Costs

Scenario 01.b			
Quality Related Costs Worksheet			
Cell Name	Clupicker Program Storage Register	AMCIA Input Value	AMCIA Output
Average annual labor cost of repair			
Present	30	829	
Projected	32	- 78	
Average annual labor cost of scrap			
Present	37	608	
Projected	32	- 78	
Annual net cost of seconds			
Present		Blank	
Projected		Blank	
Annual excess cost			
Present		Blank	
Projected		Blank	
Confidence		90	
Present value			$ 3,412
End of Calculation Sequence Step 3. Go backwards in AMCIA to Company Data Worksheet.			

Company Data Worksheet

Scenario 01.b			
Company Data Worksheet			
Cell Name	Clupicker Program Storage Register	AMCIA Input Value	AMCIA Output
Number of annual working weeks		49	
Interest on a 3 month T-bill		6	
Company tax rate		35	
Fringe benefits			
Direct Labor		23	
Indirect Labor		25	
Estimated avg. unit sale price			
Year 1		10.00	
Year 2		10.25	
Year 3		10.50	
Year 4		10.75	
Year 5		11.00	
Year 6		11.25	
Estimated production using Original Clupicker			
Year 1 - 6	44	932,262	
Estimated sales of production			
Year 1			$ 9,322,620
Year 2			$ 9,555,686
Year 3			$ 9,788,751
Year 4			$ 10,021,817
Year 5			$ 10,254,882
Year 6			$ 10,487,948
End of Calculation Sequence Step 5. Go forward in AMCIA to complete Direct Labor Worksheet Calculation Sequence Step 6.			

Investment, Installation and Depreciation Worksheet

Scenario 01.b			
Investment, Installation and Depreciation Worksheet			
Cell Name	Clupicker Program Storage Register	AMCIA Input Value	AMCIA Output
Investment for the project			
Year 0	45	- 12,000	
Original value of new equipment	- 45	+ 12,000	
Salvage value of new equipment		Blank	
Retraining expenses	46	- 112	
Installation expenses			
Year 0	47	- 356	
Depreciation tax savings			$ 3,687
Investment cash flows			- $ 12,000
Installation retraining cash flows			- $ 468
Present value	Calculate from the above 3 AMCIA outputs		- $ 8,781
End of Calculation Sequence Step 7. Go forward in AMCIA to Indirect Labor Worksheet.			

Indirect Labor Worksheet

Scenario 01.b			
Indirect Labor Worksheet			
Cell Name	Clupicker Program Storage Register	AMCIA Input Value	AMCIA Output
Indirect labor pay rate			
Present	01	4.00	
Projected	01	4.00	
Overtime costs			
Present		Blank	
Projected		Blank	
Indirect labor regular hours			
Present	49	64	
Projected	51	62	
Confidence		90	
Present value			$ 29
End of Calculation Sequence Step 8. Go to AMCIA NPV Summary Sheet.			

Appendix L - Example 01.b Net Present Value Summary

AMCIA NPV Summary For Scenario 01.b		
AMCIA Worksheet	NPV ($)	
Company Data Sheet	N/A	
Investment, Installation, and Depreciation		-8,781
Old Equipment Sale	Not Included (N/I) =>	0
Direct Labor		2,253,431
Indirect Labor		29
Materials	N/I =>	0
Maintenance	N/I =>	0
Quality Related Costs		3,412
Inventory	N/I =>	0
Fabric Utilization	N/I =>	0
Miscellaneous	N/I =>	0
Quality Revenues	N/I =>	0
Response-Time Revenues	N/I =>	0
Total		**2,248,091**

Appendix N - Initial Scenarios Reevaluated

plus Additional Scenarios

(All scenarios evaluated assuming hourly wages of $6/hr.)

Scenario 01

SCENARIOS 01 — 06

SCENARIO 01 99.5 vs 99.9

# SETUPS		1	3	6	9	12
CD	44	932262	872,116	781897	691678	601459
IID	NPV	$-8781	-$8781	-$8781	-$8781	-$8781
DA	16	84.5589	79.1035	70.9204	62.7373	54.5541
	26	92.4978	86.6766	77.9448	69.2130	60.4812
	↑	74011	60046	54924	44791	35649
	NPV	2253615	2011351	1673102	1364991	1087090
IL	49	64	186	370	554	738
	51	62	182	361	541	720
	NPV	43	86	194	280	380
OKC	30	1242	1163	1042	922	802
	32	-78	-78	-78	-78	-78
	37	746	698	625	553	481
	NPV	4271	4419	3958	3502	3046
ST	44	932262	872,116	781897	691,678	601459
NPV		2249148	2007075	1660475	1357992	1081735

T.C. 42
43

y = -106216.54 x + 2331827.17
-1.06216 54 E5 x + 2.3318272 E6
corr = -0.9987966

x	Y	x	Y
0	2.3318272 E6	27	-5.3601950 E5
50	-2.9790000 E6	28	-6.4223604 E5
100	-8.2898271 E6	21.9535215	0
150	-1.3600654 E7		
200	-1.8911481 E7		
250	-2.422309 E7		

x	Y
19	3.1371285 E5
20	2.0749630 E5
21	1.0127976 E5
22	-4.9367817 E3
23	-1.1115332 E5
24	-2.1736987 E5
25	-3.2358641 E5
26	-4.2980245 E5

SCEnario

enario 02

SCENARIO 02 97.51 vs 98.68

#SETUPS		1.	3	6	9	12
CD	44	666 447	623450	558955	494460	429 966
IID	NPV $	-8781	-8781	-8781	-8781	-8781
DL	16	60,4487	56.5488	50.6989	44.8940	38.9991
	26	72,4805	68.1370	61.6217	55.1064	48.5911
	$	50186	72247	61054	50719	9124
	NPV $	2443777	2202439	1862260	1548275	1260513
IL	49	64	186	370	554	738
	51	60	174	345	516	687
	NPV $	86	256	539	820	1100
ORC	30	4211	3939	3532	3124	2717
	32	-35	-34	-34	-33	-32
	37	2526	2363	2119	1874	1630
	NPV	7178	6523	5849	5021	4235
ST 44		666 447	623450	558955	494460	429 966
NPV$		2442260	2200437	1859867	1545335	1257067
TC	42	316	295	263	231	198
	43	229	214	192	170	148

y = -1,0780707 E5 x + 2.5243970 E6

corr = -0.99911724

x	Y	x	Y	Y	x
0	2.5243970 E6	24	-5.7912665 E4	0	2.3462255 E1
~~50~~					
50	-2.8609565 E6	25	-1.6577934 E5		
100	-8.2513101 E6	26	-2.7358681 E5		
150	-1.3641664 E7	27	-3.8139388 E5		
200	-1.9032017 E7	28	-4.8920095 E5		
250	-2.4422371 E7				
19	4.8101269 E5				
20	3.7322556 E5				
21	2.6544855 E5				
22	1.5764148 E5				
23	4.9834406 E4				

Scenario 03 - Page 1 of 2

SCENARIO 03 98.76 VS 99.23

SETUPS		1	3	6	9	12
CD	44	808526	756363	678119	599874	521630
IID	NPV $	-8781	-8781	-8781	-8781	-8781
DL	16	73.3357	68.6044	61.5074	54.4104	47.3134
	26	80.1093	75.0906	67.5627	60.0347	52.5067
	$	54766	49059	41062	33739	27090
	NPV $	1668140	1494596	1251457	1028870	826856
IL	49	64 ~~64~~	186	370	554	738
	51	62	181	360	538	717
	NPV	43	108	216	345	453
ORL	30	2624	2455	2201	1947	1693
	32	-31	-31	-31	-31	-30
	37	1575	1473	1321	1168	1016
	NPV	3963	3707	3324	2940	2474
ST	44	808526	756363	678119	599874	521630
NPV	$	1663365	1489630	1246216	1023374	820996
TC	42	362	338	302	265	228
	43	143	134	120	106	92

SCENARIO 03 CONT.

Y = -7,6628594E4 x + 1,7238135E6

Corr = -99892758E-1

x	Y	Y	x
0	1,7238135E6	0	2,2495695E1
50	-2,1076162E6		
100	-5.9340459E6		
150	-9,7704756E6		
200	-1,3606905E7		
250	-1,7433335E7		
19	2,1787020E5		
20	1,9124160E5		
21	1,1461301E5		
22	3,7984416E4		
23	-3.8644178E4		
24	-1,15272,77E5		
25	-1,91901,37E5		
26	-2,68529,96E5		
27	-3,45158,55E5		
28	-4,21787,15E5		

Scenario 04

SCENARIO 04 99.1 vs 99.5

# SETUPS		1	3	6	9	12
CD	44	860471	804957	721685	638414	555142
IID	NPV	-8781	-8781	-8781	-8781	-8781
DC	16	78.0472	73.0119	65.4596	57.9060	50.3531
	26	84.6241	79.2989	71.3112	63.3235	55.3358
	↑	56592	50608	42234	34586	27661
	NPV	1723500	1541513	1286879	1054376	842425
K	49	63.75=64	186	370	554	738
	51	62.29=62	182	361	541	720
	NPV	43	86	199	280	388
QRL	30	2094	1913	1715	1517	1319
	32	-39	-39	-39	-39	-28
	37	1227	1148	1029	910	791
	NPV	3883	3634	3258	2881	2441
ST	44	860470.87	804957	721685	638414	555142
NPV		1718645	1536452	1281550	1048756	837973
TC	42	379	351	316	278	239
	43	111	104	93	83	72

Y = -8.0116119E4 x + 1.781395166

Corr = -0.9988683

x	Y	x	Y
0	1.781395166	25	-2.2156784E5
50	-2.2249108E6	26	-3.0162396E5
100	-6.2302118E6	27	-3.8174008E5
150	-1.023602367	28	-4.6185620E5
200	-1.42418249E7		
250			

2.2235115E1 0

19	2.5918887E5
20	1.7907275E5
21	9.8956635E4
22	1.8840515E4
23	-6.1275604E4
24	-1.4139172E5

Scenario 05

SCENARIO 05 99.10 VS 99.90

# SETUPS		1	3	6	9	12
CD	44	860471	804957	721685	638414	555142
IID	NPV	-8781	-8781	-8781	-8781	-8781
DC	16	78.0472	73.0119	65.4590	57.9060	50.3531
	26	92.5673	86.8851	78.3618	69.8386	61.3153
	↑	124441	111673	93118	76179	60856
	NPV	3804922	3401324	2837091	2322056	1856240
IC	44	64	186	370	554	738
	51	61	178	353	528	703
	NPV	65	173	367	561	755
ORC	30	2044	1413	1715	1517	1319
	32	-87	-87	-86	-86	-86
	37	1227	1148	1029	910	791
	NPV	8663	8107	7184	6354	5524
ST	44	860471	804957	721685	638414	555142
NPV		3804869	3400873	2835861	2320190	1853788
TC	42	379	354	316	278	239
	43	111	104	93	83	72

y = -1.7749724E5 x + 3.9435991E6

corr = -0.9988499

x	y	x	y
0	3.9435991E6	25	-4.9383184E5
50	-4.9312627E6	26	-6.7132767E5
100	-1.3806125E7	27	-8.4882631E5
150	-2.2680986E7	28	-1.0263235E6
200	-3.1555848E7		
250	2.2217805E1		

2.2217805E1 0

19	5.7115158E5
20	3.9365434E5
21	2.1615711E5
22	3.8659871E4
23	-1.3883737E5
24	-3.1633460E5

Scenario 06

SCENARIO 06 99.20 vs 99.80

# SETUPS		1	3	6	9	12
CD	44	877232	820656	735743	650849	565956
IID		-8781	-8781	-8781	-8781	-8781
DC	16	79.5625	74.4341	66.7340	59.0340	51.3339
	26	90.4138	84.7444	76.3652	67.9361	59.5069
	9	95147	85020	70861	57939	46256
	NPV	2897512	2589503	2158917	1766029	1410920
IC	49	64	186	370	554	738
	51	62	180	357	534	711
	NPV	43	129	280	431	583
QRC	30	1857	1737	1558	1378	1198
	32	-71	-71	-71	-71	-71
	37	1114	1042	935	827	717
	NPV	6422	6007	5388	4766	4143
ST	44	877232	820656	735743	650849	565956
NPV		2895196	2586858	2155804	1762445	1406865
TC	42	385	359	320	282	243
	43	101	95	85	75	65

y = -1.35399276E5 x + 3.00090916E6

corr. = -0.99884149

x	Y
0	3.00090916E6
50	-3.76905454E6
100	-1.05390186E7
150	-1.73089826E7
200	-2.40789451E7
250	

x	Y
25	-3.84072716E5
26	-5.19471985E5
27	-6.54871256E5
28	-7.90270528E5

0

19	4.2832242E5
20	2.9292365E5
21	1.5752438E5
22	2.2125109E4
23	-1.1327416E5
24	-2.4867343E5

Scenario 07

SCENARIOS 07-12		96.5 vs 97.5			SCENARIO 07	
CD	44	587699	549783	492909	436035	379161
		1	3	6	9	12
IID	NPV	-8781	-8781	-8781	-8781	-8781
DL	16	53.3306	49.8669	44.7083	39.5496	34.3910
	26	60.4833	56.8223	51.3308	45.8393	40.3478
	↑	42036	38240	32643	27425	22586
	NPV	1281968	1166667	996696	838332	691601
IL	49	64	186	370	554	738
	51	60	175	348	521	693
	NPV	86	237	475	712	971
GRC	30	5090	4762	4269	3776	3284
	32	-17	-17	-16	-15	~~-~~14
	37	3054	2857	2561	2266	1970
	NPV	4215	3943	3327	2759	2239
ST	44	587699	549,783	492,909	436 035	379 161
NPV	:	1,277,488	1,162,066	991,717	833022	686030
TD	42	290	270	241	211	182
	43	277	259	232	206	179

y = -5.3914424 E4 x + 1.3243340 E6

CORR = -0.99946399

Q	x	Y		Y	x
	0	1,3243340 E6		0	2,4563631 E1
	50	-1,3713872 E6			
	100	-4,0671084 E6			
	150	-6,7628296 E6			
	200	-9,4585507 E6			
	250	-1,2154272 E7			
	19	2,9995947 E5			
	20	2,4604555 E5			
	21	1,9213113 E5			
	22	1.3821670 E5			
	23	8,4302279 E4			
	24	3,0387855 E4			
	25	-2,3526569 E4			
	26	-7,7440992 E4			
	27	-1,3135542 E5			
	28	-1,8526984 E5			

Scenario 08

97.5 vs 98.5 | SCENARIO 08

		1	3	6	9	12
CD	44	665541	622603	558195	493788	424,381
110 NPV		-8781	-8781	-8781	-8781	-8781
DL	16	60.3665	56.4719	50.6300	44.7881	38.9461
	26	70.2808	66.0239	59.6387	53.2535	46.8683
	9	65984	59471	50286	41801	34016
	NPV	2011030	1813054	1533924	1276171	1039820
IL	49	64	186	370	554	738
	51	60	175	348	521	694
	NPV	86	237	475	712	471
ORC	30	4221	3948	3540	3132	2723
	32	-28	-28	-28	-27	-26
	37	2532	2369	2124	1879	1634
	NPV	5756	5385	4828	4119	3449
ST	44	665541	622603	558195	493788	424381
NPV		2008091	1809895	1530446	1272221	1035459
TC	42	316	294	262	230	198
	43	230	215	193	170	148

y = -8.8476464 E4 · x + 2.0797765 E6

corr = -0.99913166

x	Y	Y	x
0	2.0797765 E6	0	2.3506550 E1
50	-2.3440467 E6		
100	-6.7678700 E6		
150	-1.1191693 E7		
200	-1.5615516 E7		
250	-2.0039340 E7		

19	3.9872365 E5
20	3.1024719 E5
21	2.2177073 E5
22	1.3329426 E5
23	4.4817797 E4
24	-4.3658669 E4
25	-1.3213513 E5
26	-2.2061160 E5
27	-3.0908806 E5
28	-3.9756453 E5

Scenario 09

98.5 vs 99.5 | Scenario 09

		1	3	6	9	12
CD	44	773364	723469	648628	573786	498944
11D	NPV	-8781	-8781	-8781	-8781	-8781
DL	16	70.1464	65.6208	58.8324	52.0441	45.2557
	26	84.7193	79.5847	71.8828	64.1809	56.4790
	9	112702	101024	84649	69639	55998
	NPV	3433043	3077911	2580019	2123944	1709235
IL	49	64	186	370	554	738
	51	60	175	348	521	694
	NPV	86	237	475	712	971
QRL	30	3017	2822	2530	2238	1946
	32	-59	-59	-58	-58	-57
	37	1810	1693	1518 ~~349~~	1343	1168
	NPV	8670	8109	7147	6323	5403
ST	44	773364	723469	648628	573786	498944
NPV		3433018	3077476	2578860	2121998	1706828
T.C.	42	351	327	292	256	221
	43	164	154	138	122	106

y = -1.570328 9 E5 x + 3.5512399 E6

corr = -0.99884738

x	y
0	3.5512399 E6
50	-4.2944047 E6
100	-1.2146049 E7
150	-1.9997694 E7
200	-2.7849339 E7
250	-3.5700983 E7
19	5.7361496 E5
20	4.1658207 E5
21	2.5954918 E5
22	1.0251628 E5
23	-5.4516609 E4
24	-2.1154950 E5
25	-3.6858240 E5
26	-5.2561529 E5
27	-6.8264818 E5
28	-8.3968108 E5

y	x
0	2.2652833 E1

Scenario 10

96.5 vs 98.5 SCENARIO 10

		1	3	6	9	12
CD	44	587,699	549783	412909	436035	379161
IID	NPV	-8781	-8781	-8781	-8781	-8781
DL	16	53.3060	49.8669	44.7083	39.5496	34.3910
	26	70.4084	66.4069	60.4047	54.4025	48.4003
	$	100511	90434	77369	64764	53118
	NPV	3064505	2773435	2361269	1978433	1624937
IL	49	64	186	370	554	738
	51	57	165	327	490	652
	NPV	151	453	928	1381	1855
DRC	30	5090	4762	4269	3776	3284
	32	-41	-40	-39	-38	-37
	37	3054	2557	2561	2266	1470
	NPV	10165	9278	8109	6989	5918
SF	44	587699	549785	412909	436035	379161
NPV		3066049	2774385	2361525	1978022	1623929
TC	42	290	270	241	211	182
	43	277	259	232	206	179

y = -1.31173806E5 x + 3.11405776E6

Corr = -0.99924864

x	Y		Y	x
0	3.11405776E6		0	2.41973466E1
50	-3.38463261E6			
100	-9.8433220E6			
150	-1.65020178E7			
200	-2.30607026E7			
250	-2.96193916E7			
19	6.81755606E5			
20	5.50581806E5			
21	4.19408016E5			
22	2.88234216E5			
23	1.57060416E5			
24	2.58866614E4			
25	-1.05287166E5			
26	-2.36460966E5			
27	-3.67634766E5			
28	-4.98808576E5			

Scenario 11

97.5 vs 99.5 | SCENARIO 11

		1	3	6	9	12
CD	44	665 541	622603	558195	493788	429 381
IID	NPV	-8781	-8781	-8781	-8781	-8781
DC	16	60.3665	56.4719	50.6300	44.7881	38.9461
	26	84.8718	80.0421	72.7476	65.5531	58.3086
	↑	163093	146749	123738	102535	83134
	NPV	4969685	4472709	3775124	3128678	2534377
IC	49	64	186	370	554	738
	51	57	165	328	491	653
	NPV	151	453	926	1381	1855
ONC	30	4221	3948	3540	3132	2723
	32	-70	-70	-70	-70	-69
	37	2532	2369	2124	1879	1634
	NPV	14390	13461	12070	10678	9152
ST	44	665541	622603	558 195	493788	429 381
NPV		4975445	4477842	3777341	3131956	2550386
TC	42	316	294	262	230	198
	43	230	215	193	170	148

y = -2.2075077 E5 x.r. 5.1512488 E6

Corr = -0.99896489

x	Y	Y	x
0	5.1512488 E6	0	2.3335134 E1
50	-5.8862894 E6		
100	-1.6923829 E7		
150	-2.7961367 E7		
200	-3.8998906 E7		
250	-5.0036445 E7		

19	9.5698409 E5
20	7.3623332 E5
21	5.1548254 E5
22	2.9473177 E5
23	7.3980995 E4
24	-1.4676978 E5
25	-3.6752055 E5
26	-5.8827133 E5
27	-8.0902210 E5
28	-1.0297729 E6

Scenario 12

96.5 vs 99.5 — SCENARIO 12

		1	3	6	9	12
CD	44	587699	549783	492909	436035	379161
11.D NPV		-8781	-8781	-8781	-8781	-8781
DC	16	53.3069	49.8670	44.7083	39.5496	34.3910
	26	85.0166	80.4767	73.6667	66.8568	60.0468
	9	186363	168287	142739	119069	97277
	NPV	5680563	5130976	4354347	3635008	2973001
IC	49	64	186	370	554	738
	51	~~54~~ 53	155	308	461	614
	NPV	237	669	1338	2006	2675
ARC	30	5080	4762	4269	3776	3284
	32	-75	-75	-75	-74	-73
	37	3054	2857	2561	2266	1970
	NPV	18594	17395	15594	13611	11676
ST	44	587699	549783	492909	436035	379161
NPV		5690613	5140259	4362498	3650625	2987352
TC	42	290	270	241	211	182
	43	277	259	232	206	179

y = -2.4573762 E5 x + 5.889842 E6

corr r = 0.99915769

x	T	Y	x
0	5.8898426 E6	0	2.39680146 E1
50	-6.3170387 E6		
100	-1.8683919 E7		
150	-3.0970800 E7		
200	-4.3257681 E7		
250	-5.5544562 E7		
19	1.2208279 E6		
20	9.7509025 E5		
21	7.2935263 E5		
22	4.8361502 E5		
23	2.3787740 E5		
24	-7.8602233 E3		
25	-2.5359784 E5		
26	-4.9933546 E5		
27	-7.4507308 E5		
28	-9.9081070 E5		

Summary Table - Page 1 of 2

Summary Table N-1 page 1 of 2				
Scenario	$CP_{Original}$	$CP_{Modified}$	Setups per Day	Net Present Value
01	99.5	99.9	1	2.249148
	99.5	99.9	3	2.007075
	99.5	99.9	6	1.668473
	99.5	99.9	9	1.359992
	99.5	99.9	12	1.081735
02	97.51	98.68	1	2.44226
	97.51	98.68	3	2.200437
	97.51	98.68	6	1.859867
	97.51	98.68	9	1.545335
	97.51	98.68	12	1.257067
03	98.76	99.23	1	1.663365
	98.76	99.23	3	1.48963
	98.76	99.23	6	1.246216
	98.76	99.23	9	1.023374
	98.76	99.23	12	.820996
04	99.1	99.5	1	1.718645
	99.1	99.5	3	1.536452
	99.1	99.5	6	1.28155
	99.1	99.5	9	1.048756
	99.1	99.5	12	.837973
05	99.1	99.9	1	3.804869
	99.1	99.9	3	3.400873
	99.1	99.9	6	2.835861
	99.1	99.9	9	2.32019
	99.1	99.9	12	1.853788
06	99.2	99.8	1	2.895196
	99.2	99.8	3	2.586858
	99.2	99.8	6	2.155804
	99.2	99.8	9	1.762445
	99.2	99.8	12	1.406865

Summary Table - Page 2 of 2

Summary Table N-1 page 2 of 2				
Scenario	$CP_{Original}$	$CP_{Modified}$	Setups per Day	Net Present Value
07	96.5	97.5	1	1.277488
	96.5	97.5	3	1.162066
	96.5	97.5	6	.991717
	96.5	97.5	9	.833022
	96.5	97.5	12	.68603
08	97.5	98.5	1	2.008091
	97.5	98.5	3	1.809895
	97.5	98.5	6	1.530446
	97.5	98.5	9	1.272221
	97.5	98.5	12	1.035459
09	98.5	99.5	1	3.433018
	98.5	99.5	3	3.077476
	98.5	99.5	6	2.57886
	98.5	99.5	9	2.121998
	98.5	99.5	12	1.706828
10	96.5	98.5	1	3.06604
	96.5	98.5	3	2.774385
	96.5	98.5	6	2.361525
	96.5	98.5	9	1.978022
	96.5	98.5	12	1.623929
11	97.5	99.5	1	4.975445
	97.5	99.5	3	4.477842
	97.5	99.5	6	3.777341
	97.5	99.5	9	3.131956
	97.5	99.5	12	2.550386
12	96.5	99.5	1	5.690613
	96.5	99.5	3	5.140259
	96.5	99.5	6	4.362498
	96.5	99.5	9	3.650625
	96.5	99.5	12	2.987352

Appendix O - Multiple Regression Analysis

All of the calculated values shown in this section were produced using a statistical package called StatView II v1.02 for Macintosh.

Y-Intercept Calculations

Input Data with Residual and Fit Output Data

Clupicker Multiple Regression Analysis of a First Order Model with Two Independent Variable where z = y-axis intercept = Net Present Value					
Scenario	Input			Output	
	Original Clupicker Performance	Modified Clupicker Performance	Net Present Value	Residual	Fit
01	99.5	99.9	2.3318272	-.3709728	2.7028
02	97.51	98.68	2.52939	-.0058428	2.5352398
03	98.76	99.23	1.7238135	-.3553608	2.0791743
04	99.1	99.5	1.7813951	-.4861319	2.267527
05	99.1	99.9	3.9435991	.63819	3.3054091
06	99.2	99.8	3.0009091	.1056228	2.8952863
07	96.5	97.5	1.324334	.3292584	.9950756
08	97.5	98.5	2.0797765	-.0034816	2.0832581
09	98.5	99.5	3.5572399	.3857993	3.1714406
10	96.5	98.5	3.1740577	-.415723	3.5897807
11	97.5	99.5	5.1512488	.4732856	4.6779632
12	96.5	99.5	5.8898426	-.2946432	6.1844858

Remaining Output Data

Multiple Regression Y_1 :NPV 2 X variables

Count:	R:	R-squared:	Adj. R-squared:	RMS Residual:
12	.9608648	.9232612	.9062081	.4294191

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test:
REGRESSION	2	19.967087	9.9835435	54.1404612
RESIDUAL	9	1.6596071	.1844008	p = .0001
TOTAL	11	21.6266941		

No Residual Statistics Computed

Here R-squared (0.9232612) implies that the data is fairly linear. An R-squared value of one (1) implies perfect linearity.

Multiple Regression Y_1 :NPV 2 X variables

Beta Coefficient Table

Variable:	Coefficient:	Std. Err.:	Std. Coeff.:	t-Value:	Probability:
INTERCEPT	-106.6092405				
Original	-1.5065226	.1643002	-1.2303903	9.1693285	.0001
Modified	2.5947051	.2584743	1.347026	10.0385421	.0001

Here the Coefficient data can be used to develop a model for calculating the y-intercept. The model is

$$y_{int.} = (-1.5065226 \text{ x } CP_{Original}) + (2.5947051 \text{ x } CP_{Modified}) - 106.6092405 \quad (O.1)$$

Where CP implies Clupicker Performance.

X-Intercept Calculations

Input Data with Residual and Fit Output Data

Clupicker Multiple Regression Analysis of a First Order Model with Two Independent Variable where z = x-axis intercept = Number of Setups per Day					
Scenario	Input			Output	
	Original Clupicker Performance	Modified Clupicker Performance	Number of Setups per Day	Residual	Fit
01	99.5	99.9	21.953522	.0444353	21.9090867
02	97.51	98.68	23.462255	-.0519122	23.5141672
03	98.76	99.23	22.495695	-.0647068	22.5604018
04	99.1	99.5	22.235165	-.0355078	22.2706728
05	99.1	99.9	22.217805	.0478129	22.1699921
06	99.2	99.8	22.163407	.0334711	22.1299359
07	96.5	97.5	24.563631	.0936696	24.4699614
08	97.5	98.5	23.506550	-.0594461	23.5659961
09	98.5	99.5	22.652833	-.0091979	22.6620309
10	96.5	98.5	24.197346	-.0209137	24.2182597
11	97.5	99.5	23.335134	.0208396	23.3142944
12	96.5	99.5	23.968014	.001456	23.966558

Remaining Output Data

Multiple Regression Y_1 :Setups 2 X variables

Count:	R:	R-squared:	Adj. R-squared:	RMS Residual:
12	.9984623	.996927	.9962441	.0545586

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test:
REGRESSION	2	8.6910374	4.3455187	1459.8732071
RESIDUAL	9	.0267898	.0029766	p = .0001
TOTAL	11	8.7178272		

Residual Information Table

SS[e(i)-e(i-1)]:	e ≥ 0:	e < 0:	DW test:
.0492967	6	6	1.8401298

Here R-squared (0.996927) implies that the data is very nearly linear. An R-squared value of one (1) implies perfect linearity.

Multiple Regression Y_1 :Setups 2 X variables

Beta Coefficient Table

Variable:	Coefficient:	Std. Err.:	Std. Coeff.:	t-Value:	Probability:
INTERCEPT	111.9543082				
Original	-.6522635	.0208747	-.8390373	31.2466254	.0001
Modified	-.2517017	.0328397	-.2058093	7.6645548	.0001

Residual : Column 4 Fitted : Column 5

Here the Coefficient data can be used to develop a model for calculating the y-intercept. The model is

$$x_{int.} = (-0.6522635 \times CP_{Original}) - (0.2517017 \times CP_{Modified}) + 111.9543082 \quad (O.2)$$

Where CP implies Clupicker Performance.

Appendix P - Performance Influences

1

CPO	CPM	SET	NPV
96.5	96.5	1	-1.2279378
96.5	96.5	12	-0.6585294
96.5	99.9	12	2.8727127
96.5	99.9	1	5.5357970
99.9	99.9	1	1.6025424
99.9	96.5	1	-5.1384882
99.9	96.5	12	-2.5099797
99.9	99.9	12	0.7488128

DETERMINED USING EQUATION DEVELOPED IN CHAPTER 4

Δ SET	Δ1	↑ 11	=>	Δ ↑ 0.5694084
	Δ2	↓ 11	=>	Δ ↑ 2.6630843
	Δ3	↑ 11	=>	Δ ↑ 2.6285085 ✓
ΔCPM	Δ1	↑ 3.4	=>	Δ ↑ 3.5312421 ✓
	Δ2	↓ 3.4	=>	Δ ↓ 6.7410306 ✓
	Δ3	↑ 3.4	=>	Δ ↑ 3.2587925
ΔCPO	Δ1	↑ 3.4	=>	Δ ↓ 3.9332546 ✓

SET	CPO	CPM	NPV
1	96.5	96.5	-1.2279378
1	96.5	99.9	5.5357970
1	99.9	99.9	1.6025424
1	99.9	96.5	- 5.1384882
12	99.9	96.5	- 2.5099797
12	96.5	96.5	- 0.6585294
12	96.5	99.9	2.8127127
12	99.9	99.9	0.7488128

Δ CPM	Δ 1	↑ 3.4	⇒	Δ ↑ 6.7637348
	Δ 2	↓ 3.4	⇒	Δ ↓ 6.7410306 ✓
	Δ 3	↑ 3.4	⇒	Δ ↑ 3.5312421 ✓
Δ CPO	Δ 1	↑ 3.4	⇒	Δ ↓ 3.9332546 ✓
	Δ 2	↓ 3.4	⇒	Δ ↑ 1.8514503
	Δ 3	↑ 3.4	⇒	Δ ↓ 2.1238999
Δ SET	Δ 1	↑ 11	⇒	Δ ↑ 2.6285085 ✓

CPM	SET	CPO	NPV
96.5	1	96.5	-1.2277378
96.5	1	99.9	-5.1384862
96.5	12	99.9	-2.5099797
96.5	12	96.5	-0.6585294
99.9	12	96.5	2.8727127
99.9	1	96.5	5.5357970
99.9	1	99.9	1.6025424
99.9	12	99.9	0.7488128

Δ CPO	Δ 1	↑ 3.4	⇒	Δ ↓ 3.9105504 ✓
	Δ 2	↓ 3.4	⇒	Δ ↑ ~~3.1685091~~ 1.8514503
	Δ 3	↑ 3.4	⇒	Δ ↓ 3.9332546 ✓
Δ SET	Δ 1	↑ 11	⇒	Δ ↑ 2.6285085
	Δ 2	↓ 11	⇒	Δ ↑ 2.6630843
	Δ 3	↑ 11	⇒	Δ ↓ 0.8531296
Δ CPM	Δ 1	↑ 3.4	⇒	Δ ↑ 3.5312421 ✓

~~ELIMINATING DUPLICATE CONDITIONS~~

TALLYING RESULTS

Δ SET

↑ 0.5694084
↑ 2.6630843
↑ 2.6285085
↑ 2.6285085 DUPLICATES
↑ 2.6285085
↑ 2.6630843
↓ 0.8537296

DUPLICATES

Δ CPM

↑ 3.5312421
↓ 6.7410306
↑ 3.2587925
↑ 6.7637348
↓ 6.7410306
↑ 3.5312421 DUPLICATES
↑ 3.5312421

DUPLICATES

Δ CPO

↓ 3.9332546
↓ 3.9332546
↑ 1.8514503
↓ 2.1238999 DUPLICATES
↓ 3.9105504
↑ 1.8514503 ~~3.1185091~~
↓ 3.9332546

DUPLICATES

5

ELIMINATING DUPLICATE CONDITIONS

Δ SET

0.5694084
2.6630843
2.6285085
~~2.6630843~~
0.8537296

MEAN = 1.5928268

Δ CPM

3.5312421
6.7410306
3.2587925
6.7637348

MEAN = 5.0737000

Δ CPO

3.9332546
1.8514503
2.1238999
3.9105504

MEAN = 2.7547888

⇓

OVER THE DATA RANGES SELECTED, THE FACTOR WITH THE GREATEST INFLUENCE ON NPV IS CPM FOLLOWED BY CPO FOLLOWED BY SET

For a discussion on this appendix see Question 4 at the end of Chapter 4.

Appendix Q - AMCIA Time Checks

Scenario 01

Scenario #01							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clupicker Perform-ance	Modified Clupicker Perform-ance	# of Clu-pickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
a	02	0.9950	0.9990	6	1	403	68
b	04	"	"	"	"	403	68
c	06	"	"	"	"	403	68
d	08	"	"	"	"	403	68
e	10	"	"	"	"	403	68
f	02	"	"	"	3	376	63
g	04	"	"	"	"	"	"
h	06	"	"	"	"	"	"
i	08	"	"	"	"	"	"
j	10	"	"	"	"	"	"
k	02	"	"	"	6	336	57
l	04	"	"	"	"	"	"
m	06	"	"	"	"	"	"
n	08	"	"	"	"	"	"
o	10	"	"	"	"	"	"
p	02	"	"	"	9	295	50
q	04	"	"	"	"	"	"
r	06	"	"	"	"	"	"
s	08	"	"	"	"	"	"
t	10	"	"	"	"	"	"
u	02	"	"	"	12	255	44
v	04	"	"	"	"	"	"
w	06	"	"	"	"	"	"
x	08	"	"	"	"	"	"
y	10	"	"	"	"	"	"

* Clupicker-Program Register-# (see Appendix J).

Scenario 02

Scenario #02							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-scenarios	Hourly Wages ($/hr)	Original Clupicker Performance	Modified Clupicker Performance	# of Clupickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
a	02	0.9751	0.9868	6	1	316	229
c	06	"	"	"	"	"	"
e	10	"	"	"	"	"	"
f	02	"	"	"	3	295	214
h	06	"	"	"	"	"	"
j	10	"	"	"	"	"	"
k	02	"	"	"	6	263	192
m	06	"	"	"	"	"	"
o	10	"	"	"	"	"	"
p	02	"	"	"	9	231	170
r	06	"	"	"	"	"	"
t	10	"	"	"	"	"	"
u	02	"	"	"	12	198	148
w	06	"	"	"	"	"	"
y	10	"	"	"	"	"	"

* Clupicker-Program Register-# (see Appendix J).

Scenario 03

Scenario #03							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clupicker Perform-ance	Modified Clupicker Perform-ance	# of Clu-pickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
c	06	0.9876	0.9923	6	1	362	143
h	"	"	"	"	3	338	134
m	"	"	"	"	6	302	120
r	"	"	"	"	9	265	106
w	"	"	"	"	12	228	92
* Clupicker-Program Register-# (see Appendix J).							

Scenario 04

Scenario #04							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clupicker Perform-ance	Modified Clupicker Perform-ance	# of Clu-pickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
c	06	0.9910	0.9950	6	1	379	111
h	"	"	"	"	3	354	104
m	"	"	"	"	6	316	93
r	"	"	"	"	9	278	83
w	"	"	"	"	12	239	72
* Clupicker-Program Register-# (see Appendix J).							

Scenario 05

Scenario #05							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clupicker Perform-ance	Modified Clupicker Perform-ance	# of Clu-pickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
c	06	0.9910	0.9990	6	1	379	111
h	"	"	"	"	3	354	104
m	"	"	"	"	6	316	93
r	"	"	"	"	9	278	83
w	"	"	"	"	12	239	72
* Clupicker-Program Register-# (see Appendix J).							

Scenario 06

Scenario #06							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clupicker Perform-ance	Modified Clupicker Perform-ance	# of Clu-pickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
c	06	0.9876	0.9923	6	1	385	101
h	"	"	"	"	3	359	95
m	"	"	"	"	6	320	85
r	"	"	"	"	9	282	75
w	"	"	"	"	12	243	65
* Clupicker-Program Register-# (see Appendix J).							

Scenario 07

Scenario #07							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clupicker Perform-ance	Modified Clupicker Perform-ance	# of Clu-pickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
c	06	0.9910	0.9990	6	1	290	277
h	"	"	"	"	3	270	259
m	"	"	"	"	6	241	232
r	"	"	"	"	9	211	206
w	"	"	"	"	12	182	179
* Clupicker-Program Register-# (see Appendix J).							

Scenario 08

Scenario #08							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clupicker Perform-ance	Modified Clupicker Perform-ance	# of Clu-pickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
c	06	0.9876	0.9923	6	1	316	230
h	"	"	"	"	3	294	215
m	"	"	"	"	6	162	193
r	"	"	"	"	9	230	170
w	"	"	"	"	12	198	148
* Clupicker-Program Register-# (see Appendix J).							

Scenario 09

Scenario #09							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clupicker Perform-ance	Modified Clupicker Perform-ance	# of Clu-pickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
c	06	0.9910	0.9990	6	1	351	164
h	"	"	"	"	3	327	154
m	"	"	"	"	6	292	138
r	"	"	"	"	9	256	122
w	"	"	"	"	12	221	106
* Clupicker-Program Register-# (see Appendix J).							

Scenario 10

Scenario #10							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clupicker Perform-ance	Modified Clupicker Perform-ance	# of Clu-pickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
c	06	0.9876	0.9923	6	1	290	277
h	"	"	"	"	3	270	259
m	"	"	"	"	6	241	232
r	"	"	"	"	9	211	206
w	"	"	"	"	12	182	179
* Clupicker-Program Register-# (see Appendix J).							

Scenario 11

Scenario #11							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clupicker Perform-ance	Modified Clupicker Perform-ance	# of Clu-pickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
c	06	0.9910	0.9990	6	1	316	230
h	"	"	"	"	3	294	215
m	"	"	"	"	6	262	193
r	"	"	"	"	9	230	170
w	"	"	"	"	12	198	148
* Clupicker-Program Register-# (see Appendix J).							

Scenario 12

Scenario #12							
	Inputs					Outputs	
	01*	02	03	04	05	42	43
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clupicker Perform-ance	Modified Clupicker Perform-ance	# of Clu-pickers	# of Style Changes per Day	Time Available for Repairs	Time Needed for Repairs
c	06	0.9876	0.9923	6	1	290	277
h	"	"	"	"	3	270	259
m	"	"	"	"	6	241	232
r	"	"	"	"	9	211	206
w	"	"	"	"	12	182	179
* Clupicker-Program Register-# (see Appendix J).							

Appendix R - Minimum Clupicker Performance Requirements

Scenario 13 - Six Clupickers

Scenario #06								
	Inputs					Outputs		
	01*	02	03	04	05	42	43	44
Sub-sce-nar-ios	Hourly Wages ($/hr)	Original Clu-picker Perform-ance	Modified Clu-picker Perform-ance	# of Clu-pickers	# of Styles per Day	Time Avail-able for Repairs	Time Needed for Repairs	Original Yearly Produc-tion
	04	0.8500	0.9500	6	0	201.82	468.09	306873
	06	0.8500	0.9500	"	0	201.82	468.09	306873
	"	0.8500	1.0000	"	0	201.82	468.09	306873
	"	0.9627	"	"	0	294.91	295.29	591251
a	"	**0.9628**	"	"	0	295.13	294.90	591901
	"	0.9628	"	"	1	285.43	285.69	573404
b	"	**0.9629**	"	"	1	285.64	285.30	574035
	"	0.9630	"	"	3	266.44	266.54	537593
c	"	**0.9631**	"	"	3	266.63	266.17	538187
	"	0.9633	"	"	6	237.85	237.99	483581
d	"	**0.9634**	"	"	6	238.02	237.66	484118
	"	0.9637	"	"	9	209.30	209.37	429690
e	"	**0.9638**	"	"	9	209.45	209.08	430170
	"	0.9642	"	"	12	180.73	180.79	375742
f	"	**0.9643**	"	"	12	180.87	180.53	376165
	"	0.9648	"	"	15	152.08	152.35	321554
g	"	**0.9649**	"	"	15	152.20	152.13	321920
	"	0.9666	"	"	20	104.50	104.65	231740
h	"	**0.9667**	"	"	20	104.59	104.48	232011
	"	0.9706	"	"	25	56.90	56.97	141895
i	"	**0.9707**	"	"	25	56.96	56.86	142073
	"	0.9874	"	"	30	9.29	9.33	51980
j	"	**0.9875**	"	"	30	9.32	9.27	52071
	"	0.9999	"	"	31	- 0.37	0.05	33582
	"	0.99999	"	"	31	- 0.35	0.005	33656
	"	Anything	"	"	32	Not Possible		
* Clupicker-Program Register-# (see Appendix J).								
Bold performance values are minimum acceptable values.								

Scenario 14 - Twelve Clupickers, Assuming Strong Interaction

Scenario #07								
	Inputs					Outputs		
	01*		02	04	05	42	43	44
Sub-sce-nar-ios	Hourly Wages ($/hr)	Indivi-dual Clu-picker Perform-ance	Group Clu-picker Perform-ance	# of Clu-pickers	# of Styles per Day	Time Avail-able for Repairs	Time Needed for Repairs	Original Yearly Produc-tion
a	06	**0.8071**	0.9628	12	0	295.13	294.90	591901
b	"	**0.8074**	0.9629	"	1	285.64	285.30	574035
c	"	**0.8079**	0.9631	"	3	266.63	266.17	538187
d	"	**0.8087**	0.9634	"	6	238.02	237.66	484118
e	"	**0.8097**	0.9638	"	9	209.45	209.08	430170
f	"	**0.8111**	0.9643	"	12	180.87	180.53	376165
g	"	**0.8127**	0.9649	"	15	152.20	152.13	321920
h	"	**0.8175**	0.9667	"	20	104.59	104.48	232011
i	"	**0.8288**	0.9707	"	25	56.96	56.86	142073
j	"	**0.8882**	0.9875	"	30	9.32	9.27	52071
	"	0.9900	0.9999	"	31	- 0.37	0.05	33582
	"	0.9968	0.99999	"	31	- 0.35	0.005	33656
	"	N/A	Anything	"	32	Not Possible		
* Clupicker-Program Register-# (see Appendix J).								
Bold performance values are minimum acceptable values.								

As discussed in Chapter 1, Clupickers placed close together will successfully pick even if one Clupicker fails. To determine the picking performance of two Clupickers side-by-side, the following logic applies.

If the failure rate of a single Clupicker is "z" (for example: $z = 0.005$) then the success rate of the same Clupicker "x" is $x = 1 - z$ (or 0.995).

Two Clupickers placed side-by-side will have a failure rate of z^2 (which equals 0.000025) or a success rate "y" such that $y = 1 - z^2$ (which equals 0.999975).

Since the success rate of a Clupicker was identified as $x = 1 - z$, rearranging yields: $z = (1 - x)$.

Plugging the new equation for "z" into the equation for "y" yields:

$$y = 1 - (1 - x)^2 \qquad \text{Equation P.1}$$

where "x" is the individual Clupicker success rate, and "y" is the paired Clupicker success rate.

Rearranging Equation P.1 yields:

$$x = -\{[-(y - 1)]^{1/2} - 1\} \qquad (P.2)$$

This equation can be used to determine the individual Clupicker performance ratings (x) of paired Clupickers if a specific picking performance (y) is required.

For example: if a two closely spaced Clupickers are to have a minimum performance rating of 0.9628, then Equation P.2 becomes:

$$\begin{aligned} x &= -\{[-(0.9628 - 1)]^{1/2} - 1\} \\ &= -\{[-(-0.0372)]^{1/2} - 1\} \\ &= -(0.1929 - 1) \\ &= 0.8071 \end{aligned}$$

So, two closely spaced Clupicker with individual performances of 0.8071 will have a group performance of 0.9628. For other values see the table above.

It is left as an exercise to the reader to verify that for "n" Clupickers grouped close together, Equation P.2 can be expressed as:

$$x = -\{[-(y - 1)]^{1/n} - 1\} \qquad (P.3)$$

Scenario 15 - Eighteen Clupickers, Assuming Strong Interactions

Scenario #08								
	Inputs					Outputs		
	01*		02	04	05	42	43	44
Sub-sce-nar-ios	Hourly Wages ($/hr)	Indivi-dual Clu-picker Perform-ance	Group Clu-picker Perform-ance	# of Clu-pickers	# of Styles per Day	Time Avail-able for Repairs	Time Needed for Repairs	Original Yearly Produc-tion
a	06	**0.6662**	0.9628	18	0	295.13	294.90	591901
b	"	**0.6665**	0.9629	"	1	285.64	285.30	574035
c	"	**0.6671**	0.9631	"	3	266.63	266.17	538187
d	"	**0.6680**	0.9634	"	6	238.02	237.66	484118
e	"	**0.6692**	0.9638	"	9	209.45	209.08	430170
f	"	**0.6707**	0.9643	"	12	180.87	180.53	376165
g	"	**0.6726**	0.9649	"	15	152.20	152.13	321920
h	"	**0.6783**	0.9667	"	20	104.59	104.48	232011
i	"	**0.6917**	0.9707	"	25	56.96	56.86	142073
j	"	**0.7679**	0.9875	"	30	9.32	9.27	52071
	"	0.9536	0.9999	"	31	- 0.37	0.05	33582
	"	0.9785	0.99999	"	31	- 0.35	0.005	33656
	"	N/A	Anything	"	32	Not Possible		
* Clupicker-Program Register-# (see Appendix J).								
Bold performance values are minimum acceptable values.								

Equation P.3 (shown below for convenience) can be used to calculate the individual Clupicker performance (x) required to meet the group performance (y) if "n" is the number of Clupickers in the closely spaced group.

$$x = -\{[-(y - 1)]^{1/n} - 1\} \qquad \text{(P.3)}$$

For example: if a three closely spaced Clupickers are to have a minimum performance rating of 0.9628, then Equation P.3 becomes:

$$
\begin{aligned}
x &= -\{[-(0.9628 - 1)]^{1/3} - 1\} \\
&= -\{[-(-0.0372)]^{1/3} - 1\} \\
&= -(0.3338 - 1) \\
&= 0.6662
\end{aligned}
$$

So, three closely spaced Clupicker with individual performances of 0.6662 will have a group performance of 0.9628.

Glossary

AMCIA — Apparel Manufacturer's Capital Investment Advisor. A capital investment program written in part by Dr. Steve Davis, Professor of Management and Computer Science, Clemson University. AMCIA is available **free** from Clemson Apparel Research and runs on any computer with Microsoft Excel 4.0 or higher.

Bologna Slicer — A device constructed by Clemson Apparel Research to make the reuse of test bundles possible. See Chapter 2 page 2 -7.

CAR — Clemson Apparel Research, 500 Lebanon Rd., Pendleton, SC 29670. Phone: 803/646-8454.

centerplaite — The front and center portion of a shirt which contains the button holes and used to close the shirt.

Clupicker — A device designed to separate or "pick" the top-most ply off of a neat bundle of stacked and cut parts. Clupickers perform this task using a serrated (toothed) wheel. Clupickers were originally designed at Cluett-Peabody, and are currently being made by Jet Sew Inc., Barneveld, N.Y..

Clupicker Performance Model - A mathematical model use to calculate the Scenario Line of any specified Production Scenario.

Correction Factor 1 — A correction factor derived from pre-experimental data and used to bias data results in favor of the Original Clupickers.

Correction Factor 2 — A correction factor derived from Post-experimental Data "A" and "B" and used to bias data results in favor of the Original Clupickers.

critical production-time-path - A refined production-model which only looks at the time that must be used during a typical day of manufacturing to keep the Hemmer running.

design team	Dr. Tim Clapp, Professor, NCSU Keith Daniel, Textile Egr. Grad. Student, NCSU John Beaton, Textile Egr. Grad. Student, NCSU Ernst Schramayr, President, Jet Sew Bob Beasock, Project Engineer, Jet Sew Brion Dote, Design Engineer, Jet Sew Tony Aspland, Project Engineer, CAR,
hemmer	An automatic machine used to fold and sew the Centerplaite before the button holes are added.
Input parameters	Hourly wages ($/hr.), Original Clupicker Performance (%), Modified Clupicker Performance (%), and Setups per Day.
Loader	An automatic device that loads (or feeds) freshly cut shirt fronts into the Hemmer.
Modified Clupicker	A Clupicker based on Dr. Tim Clapp's (Professor of Textile Engineering, North Carolina State University) concept of a self-adjusting pickup device.
NCSU	North Carolina State University, Raleigh, NC.
Original Clupicker	A Clupicker made prior to Phase II of the Clupicker Project.
pickup device	Any device designed to separate or "pick" the top-most ply off of a neat bundle of stacked and cut parts. Examples include Clupickers, needle pickers, tape pickers, electrostatic pickers, vacuum pickers, Walton pickers, and more.
Post-experimental Data "A"	- Data which shows that Clupicker 5's performance deteriorated during the coarse of the actual experiment.
Post-experimental Data "B"	- Data which shows that Clupicker 5's performance did not directly affect the performance of the other Clupickers.
production scenario	One of a large number of mathematical models of production environments. All of the production scenarios were based on the same underlying assumptions, but each scenario had its own unique input parameters and its own unique Scenario line.
Scenario Line	A line on a graph that relates Net Present Value to Setups per Day for a particular Production Scenario.
test team	Tony Aspland, Project Engineer, CAR, Madhusudan Nagaraja, Egr. Associate, CAR
Time-based Production-model	- A mathematical model of Hemmer performance which looks at the Jet Sew Hemmer and Loader as a single unit. The model accounts

	for how time is used during daily a typical day of manufacturing.
time check	A mathematical process which ensures that the time needed to keep the Hemmer running does not exceed the time available.